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NEW YORK MEETING, DECEMBER 4-7, 1906

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

SUPPLEMENT

NOVEMBER, 1906

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THE AMERICAN SOCIETY OF
MECHANICAL ENGINEERS

PROCEEDINGS

SUPPLEMENT

CONTAINING PAPERS
TO BE PRESENTED AT THE NEW YORK MEETING
DECEMBER 4-7, 1906

PUBLISHED MONTHLY BY
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 28 NOVEMBER, 1906 NUMBER 2

BRING THIS COPY WITH YOU TO THE MEETING

The professional papers contained in this number of Proceedings are sent to you that you may prepare any discussion of them which you may wish to present. They are issued to the membership in confidence, and with the distinct understanding that they are not to be given to the press or to the public until after they have been presented at the meeting. All papers are subject to revision.

"The Society as a body is not responsible for the statements of facts or opinion advanced in papers or discussions." (C 55)

ANNOUNCEMENTS

Members should bring the October, November, and November Supplementary Proceedings with them to the meeting. It is obvious that the Society cannot furnish duplicate copies to all who attend, and it is therefore expected that the members will provide themselves with their own copies as largely as possible.

Discussion should be sent in as early as possible. This is important to us as well as to the writer, as persons who send in written discussion have precedence at the meeting over those who offer their remarks in oral form.

The Secretary is pleased to announce that the Society will have monthly meetings on the second Tuesday of each month, viz: January 8, February 12, March 12, April 9, etc.

This notice is given with the idea of encouraging members to reserve this evening for the Society meetings.

APPOINTMENTS

Under the provisions of the By-Laws (B 33) the Society has appointed delegates for various gatherings of engineering interest.

Messrs. W. F. M. Goss, P. W. Gates, and George H. Barrus have been appointed representatives of this Society on the Advisory Board to coöperate with the Fuel Testing Board of the U. S. Geological Sur-

vey. Messrs. H. L. Terwilliger and George Schlesinger were appointed Honorary Vice-Presidents to represent the Society at the 50th Anniversary of the Verein Deutscher Ingenieure in Berlin, Germany. Mr. John R. Freeman has been appointed a member of the special committee of the National Protection Association to report on the San Francisco disaster.

Messrs. John Fritz, F. R. Hutton and F. W. Taylor were appointed to represent the Society at the public exercises connected with the dedication of the Engineering Building of the University of Pennsylvania, Philadelphia, October 19.

Under the By-Laws these gentlemen were by reason of these appointments designated Honorary Vice-Presidents.

REGISTRATION AT THE ANNUAL MEETING

The method of registration which has been used at recent meetings and which has proved satisfactory in its results, will be continued.

On entering the headquarters' room during the meeting at 44 West Twenty-seventh Street, the registration desk will be found on the right and each member or guest is requested to go to this desk where he will receive a blank form, similar to the following:

No_____

NAME _____

Grade or Guest of_____

Home Address_____

_____

Convention Address_____

_____

Remarks _____

_____ **Date**_____

FAC-SIMILE OF REGISTRATION BLANKS

It is requested that he fill out this form, furnishing thereby an original and two carbon copies to be used for the regular register of attendance. In filling out these blanks, it is desired that the members

write with hard pencils which will be furnished, and that the writing be heavy and plain so that there will be no trouble for the printer in deciphering the names, thus adding much to the accuracy of the registers.

We have provided facilities this year to relieve the congestion at the registration desk, but members will aid by falling in line as they approach the desk to register and by immediately leaving and giving others the chance as soon as they have received the member's button, etc.

INTERNATIONAL MARITIME EXPOSITION

International Maritime Exposition, organized by the League Maritime Française in celebration of a century of steam navigation, will be held in the city of Bordeaux, May–November, 1907. The Exposition will be held under the official patronage and aid of the French Government and the Department of the Gironde, the Municipality, the Chamber of Commerce, and the Philomathic Society of Bordeaux. It is open to all countries. It will receive all industrial, agricultural or artistic products pertaining to maritime affairs. A colonial section will be devoted to colonial products which are intimately related to the commerce of Bordeaux. Pavilions will be devoted to ocean geography, nautical automobilism, and aerial navigation.

It is also the intention of the Commissioner General to organize congresses, competitions, and lectures on subjects concerning maritime affairs, science, art, industry, commerce, and social economy.

THE TECHNOLEXICON

"The Technolexicon" of the Society of German Engineers is a universal dictionary for translation purposes, in English, German, and French.

A report of the work from Dr. Hubert Jansen, Editor in Chief, Berlin, says that alphabetizing has so far advanced that printing will begin early in 1907. Over 3,000,000 word-cards have been collected. About 2000 firms and individual collaborators at home and abroad are assisting in the compilation of this work. Printing will begin early in 1907.

The following letter has been received from Dr. Hubert Janseu, Editor-in-Chief of the "Technolexicon."

Members of the Society are invited to correspond with the Secretary on this subject to aid him in appointing collaborators on this work.

Secretary, The American Society of Mechanical Engineers:

DEAR SIR: The "Technolexicon" of the Society of German Engineers is now so far advanced that printing will begin soon. A number of our collaborators have offered us their assistance in proofreading, which we have most gratefully accepted. It is needless to say that in the compilation of a work of such vast scope as the "Technolexicon" doubts and errors must occur, and these can only be satisfied and corrected with the help of a great number of technical proof readers. At a meeting of the Institution of Mechanical Engineers, London, the proposal was made that our proofs should be laid out in their reading-room, so that the members could make corrections or additions as they glanced through them. This very acceptable proposal will be carried out. We shall also ask the same help of several other prominent societies, and we hope that you also will permit us to send you proofs for this occasional and entirely voluntary work. Besides, however, we should be very much obliged to you, if you would designate some members of your Society who would give our proofs a closer and above all a regular attention.

To get an exact idea of the extent of the necessary corrections, we intend to send out in a short time some pages partly in manuscript, partly as rough proofs. You will therefore very much oblige us by an early answer.

We remain, dear Sir,

Yours very truly,

DR. HUBERT JANSEN,
Editor-in-Chief.

A LETTER FROM THE SECRETARY

The retiring Secretary of the Society has thought that it would be interesting to the membership if a brief statement were made to the Society and to the public through this official channel.

Mr. Calvin W. Rice has been serving the Society since June, 1906, as Assistant to the Secretary, upon an understanding that at the end of my term, at the annual meeting of December, 1906, he would become the Secretary of the Society by due process of election under the provisions of the Constitution. The intervening months have given opportunity for my successor in the office of Secretary to become familiar with its duties and serve a species of apprenticeship in some of the precedents and practices of the Society's management.

Mr. Rice has been serving as Chairman of the Meetings Committee which has brought him in close touch with the problems of that particular department; by his work as Assistant to the Secretary, he has been familiarized with other departments of the office routine.

Mr. Rice graduated from the Massachusetts Institute of Technology in Boston After graduation and until 1895 he was with the General Electric Company, working up to the position of one of their assistant engineers. In that year he was made local engineer for the company in Cincinnati, Ohio. In 1895-96 he was electrical superintendent of the Silver Lake Mines of Silverton, Colorado, and later consulting engineer of the Anaconda Copper Mining Company at Butte, Montana, engaged particularly in that company's steam and hydraulic power work. In 1898 he returned to the neighborhood of New York, serving first as electrical engineer for the Kings County Electric Light and Power Company, and later for the Consolidated Telegraph and Electrical Subway Company. This latter was the company operating the high tension electric subways of New York City.

While with the New York Edison Company Mr. Rice was Chief of the Meter and Testing Department. He has also served as 2d Vice-President and Manager of the Nernst Lamp Company of Pittsburg. In 1904 he became Consulting Engineer with the General Electric Company located in their New York office.

Through his New England descent Mr. Rice is a member of the Society of Colonial Wars. He is a member of the American Institute of Electrical Engineers and of the Institution of Electrical Engineers of Great Britain. He has the distinction of having been proposed for the latter body by Lord Kelvin, recognized as perhaps the leading scientist of the world in the fields of physics and electricity.

Mr. Rice enters upon his duties at the threshold of a new era of coöperation among the engineering societies and his experience in large oragnizations renders his selection a particularly fortunate one. He is very fortunate on the personal side, both by temperament and by training to take the difficult and exacting responsibilities which will be his.

In the old days of border warfare in Scotland, the clans kept bonfires ready to be ignited on the commanding heights, and when occasion arose the first beacon of communication was fired and a runner with a torch lit at the first fire carried this torch to the next beacon, and passed his brand to a successor who ran with it over the next stage. In writing this appreciation the undersigned hands the torch of zeal and ambition over to the capable hands of his successor.

F. R. Hutton,
Secretary.

PROGRAM OF THE ANNUAL MEETING

The Annual Meeting will be held in the auditorium of the New York Edison Company, 44 West Twenty-seventh Street, where the official headquarters will be opened Tuesday, December 4, at noon, and maintained throughout the meeting. Members and guests are requested to register as early as possible and to make this the opportunity to turn in their railroad certificates.

OPENING SESSION

Tuesday Evening, December 4, 8.45 o'clock

President's Address by Mr. Fred W. Taylor, Philadelphia, Pa., on "The Art of Cutting Metals."

SOCIAL REUNION

The reading of the President's Address will be followed by a social gathering, during which refreshments will be served. Ladies will be especially welcome at this session.

SECOND SESSION

Wednesday morning, December 5, at 9.30 o'clock

Annual business meeting. The annual reports of the Council, Tellers, Standing and Special Committees will be presented. New business can be presented at this session or at the Friday morning session.

Report of the Committee on Standard Proportions for Machine Screws.

Discussion on President's Address: "The Art of Cutting Metals."

In order not to curtail unduly the time to be devoted to the Social Reunion at the Opening Session, it has been decided to postpone the discussion of the President's Address until the Second Session, when ample time will be afforded for this purpose.

This session will adjourn punctually at 1 o'clock to the floor below, where buffet luncheon will be served.

THIRD SESSION

Wednesday afternoon, December 5, at 2 o'clock

POWER PLANT SYMPOSIUM

"The Evolution of Gas Power," by Mr. F. E. Junge, of Berlin, Germany.

"Producer Gas Power Plant," by Mr. J. R. Bibbins, of Pittsburg, Pa.

"Steam Turbine Characteristics," by Mr. Hans Holzwarth, of Hamilton, Ohio.

"A High Duty Air Compressor," by Prof. O. P. Hood, of Houghton, Mich.

"Design of an Improved Boiler Setting," by Mr. A. Bement, of Chicago, Ill.

"The Steam Plant of the White Motor Car," by Prof. R. C. Carpenter, of Ithaca, N. Y.

Wednesday evening unassigned

FOURTH SESSION

Thursday morning, December 6, at 10 o'clock

"Saw-Tooth Roof Construction," by Mr. F. S. Hinds, of Boston, Mass.

"Ferroinclave Roof Construction," by Mr. A. E. Brown, of Cleveland, O.

"Saw-Tooth Roofs for Factories," by Mr. K. C. Richmond, of Providence, R. I.

"Weights and Measures," by Mr. Henry R. Towne, of New York, N. Y.

EXCURSION

Thursday afternoon, December 6, at 2 o'clock

The excursion will be over the new electrically equipped lines of N. Y. C. & H. R. R. R. The start will be made from Grand Central Station.

RECEPTION

Thursday evening, December 6, at 9 o'clock

To be held at Sherry's, Forty-fourth Street and Fifth Avenue, entrance on Forty-fourth Street.

The President and President-elect will receive the members and guests. Dancing will follow the reception and will continue throughout the evening. Supper will be served from 10 until 12 o'clock. In order to avoid crowding, it is suggested that if those who must go out of town be served as soon after ten o'clock as possible and those who live in town delay their luncheon, all may be served with convenience. This is the only distinctively social feature of the meeting and the attendance of the visiting ladies is especially desired. It is urged that no one shall remain away because the exigencies of travel have made evening dress inconvenient. Cards of admission will

be required from all members and guests. These can be procured at the Registration Desk.

CLOSING SESSION

Friday morning, December 7, at 10 o'clock

"Mechanical Engineering Index," by Prof. W. W. Bird and Prof. A. L. Smith, Worcester, Mass.

"Ventilation of Boston Subway," by Mr. H. A. Carson, of Boston, Mass.

"Flow of Fluids in Venturi Tubes," by Mr. E. P. Coleman, of Buffalo, N. Y.

"Tests of an Elevator Plant," by Mr. A. J. Herschmann, of New York, N. Y.

"Test of a Rotary Pump," by Prof. W. B. Gregory, of New Orleans, La.

"Improved Transmission Dynamometer," by Mr. W. F. Durand, of Stanford University, Cal.

"A Plan to Provide Skilled Workmen," by Mr. M. W. Alexander, of Lynn, Mass.

RAILWAY TRANSPORTATION NOTICE

Instructions in Regard to Purchase of Railway Tickets for Those Attending the Annual Meeting

Certificate rates of a fare and a third for round trip have been secured for members and guests attending the Annual Meeting. A brief statement of the steps to be taken to secure this rate is given in heavy faced type. The balance of this announcement gives all the particulars.

a. Obtain a certificate when you purchase your ticket to New York.

b. Hand in this certificate with 25 cents when you register at Headquarters, or not later than December 7.

c. Call later at Registration Desk at Headquarters and get your certificate after it has been signed by Mr. Hoadley and the Railway Agent.

Arrangements have been made with the principal railway associations, by which those attending this meeting may secure the rate of one and one-third fare for the round trip, according to the "certificate plan." A person buying a ticket to New York, on November 30 to December 6 inclusive, and obtaining a certificate from the ticket agent at the time of purchase can secure at New York, up to December 11, a non-transferable return ticket for continuous trip over the same route for one-third the regular "limited" fare. This arrangement is subject to the important condition stated below, to which attention is specially called.

The concession of one-third fare for the return ticket is subject to the imperative condition that at least one hundred persons holding the certificates above described shall present the same to Mr. Francis W. Hoadley, Assistant to Secretary, Badge No. 4, with 25 cents for fee to Railroad Association, not later than December 7, and have them endorsed by him, to be subsequently endorsed by the agent of the railway associations at New York. It is necessary that we should have one hundred certificates in hand before the railway agent can endorse the first one. If that number is not actually produced, the whole arrangement becomes void, and even those who have certificates will be obliged to pay full fare in return. This is a matter over which we have no control, and can only state the case and ask the

hearty coöperation of members. Experience at past meetings has shown that members not caring to avail themselves of the "certificate plan" (because they wish to stay longer or to return by another route or to stop over by the way), often neglect to take certificates. Attention is therefore called to the following directions and requests.

Whether you mean to use the certificate or not, and if you buy a straight ticket, obtain a certificate from the ticket agent, naming the meeting of The American Society of Mechanical Engineers, as the purpose of the trip. Certificates are not kept at all stations. If, however, the ticket agent at a local station is not supplied with certificates and through tickets to place of meeting, he can inform you of the nearest important station where they can be obtained. In such a case you should purchase a local ticket to such station and there take up your certificate and through ticket to place of meeting. In many cases an agent at a station of minor importance will, upon request, secure the certificate or the through ticket, or both, when sufficient time is afforded him to do so. It costs nothing to secure certificates and by doing it you may render an important service to fellow-members. It is especially urged that everyone secure a certificate of the purchase of his going ticket, even if not intending to avail himself of reduced rate on the return. By handing the certificate to Mr. Hoadley or one of his assistants at the Registration Desk, it will help to secure the concession for others. No refund of fare can be made on account of any person failing to secure a certificate.

At the close of this announcement will be found a list of the associations from whom we have heard up to the present time concerning this rate.

To prevent all misunderstanding, call beforehand on the ticket agent of whom you mean to purchase your ticket, and find out whether his office has the appropriate blanks and instructions. In case of difficulty, write at once to the undersigned; and that you may have time to do this, make your preliminary inquiry in ample season.

No special delegates' tickets or certificates can be transferred to scalpers or brokers. The Society has to redeem at full fare any tickets which are so detected.

No certificate can be signed by Mr. Hoadley or the railway agent after December 7, therefore turn them in promptly when you register on arrival at Headquarters. We must get one hundred together before any can be endorsed by the railway agent. Delay in presenting your certificate may seriously affect others.

Arrangements for transportation, as explained above, hotel accommodation, etc., should be made personally by each member attending the meeting.

Up to the time of going to press the following railroad associations have advised us that the certificate rate has been granted:

Trunk Line Association, covering the following territory:

Niagara Falls, Buffalo, Dunkirk, and Salamanca, N. Y., Erie and Pittsburg, Pa., Bellaire, O., Wheeling, Parkersburg and Huntington, W. Va., and points east thereof, except in New England, comprising the following lines:

Baltimore & Ohio (Parkersburg, Bellaire and Wheeling, and east thereof),
Buffalo & Susquehanna,
Buffalo, Rochester & Pittsburg,
Central of New Jersey,
Chesapeake & Ohio (Huntington, W. Va., and east thereof),
Chesapeake Steamship Co.,
Cumberland Valley,
Delaware & Hudson,
Delaware, Lackawanna & Western,
Erie (Buffalo, Suspension Bridge, Dunkirk, Salamanca and east thereof),
Fonda, Johnstown & Gloversville,
Jamestown, Chautauqua & Lake Erie,
Lehigh Valley,
New York Central & Hudson River, Main Line and Branches, including R. W. & O., Adirondack and Penna. Divisions, but not including stations on the Harlem and Putnam Divisions.
New York, Ontario & Western,
New York, Phila. & Norfolk,
Norfolk & Washington Steamboat Co.,
Pennsylvania, including Buffalo & Allegheny Valley Division (formerly W. N. Y. & P. and Allegheny Valley Railways),
Northern Central,
Philadelphia & Erie,
Philadelphia, Baltimore & Washington,
Washington Southern,
West Jersey & Seashore,
Philadelphia & Reading,
Pittsburg, Shawmut & Northern,
Washington Southern,
Western Maryland,
West Shore.

Central Passenger Association, covering the following territory:

Bounded on the East by Pittsburg, Salamanca, Buffalo and Toronto; on the North the line of, and including points on the Grand Trunk Railway, from Toronto to Port Huron, thence via Lakes Huron and Michigan to Chicago; on the West by Peoria and Keokuk, Quincy, Hannibal, St. Louis and Cairo; and on the South by the Ohio River, but including points on either side of that river:

Ann Arbor R. R.,
B. & O. R. R.,
B. & O. S. W. R. R.,
B. & L. E. R. R.,
Big Four Route,
C. & O. Ry,
Chicago & Alton R. R.,
C. & E. I. R. R.,
C. & E. and Erie R. R.,
C. I. & E. R'y,
C. I. & L. R'y,
C. I. & S. R. R.,
C. R. I. & P. R'y (between Chicago and Peoria, via Bureau),
C. & M. V. R. R.,
C. H. & D. R'y,
C. N. O. & T. P. R'y,
Cin. Northern R. R.,
C. A. & C. R'y,
C. & B. Transit Co.,
C. C. & L. R. R.,
Dayton & Union R. R.,
D. & B. S. Co.,
D. & C. N. Co.,
D. T. & I. R'y,
D. T. & M. R. R.,
D. A. V. & P. R. R.,
E. & I. R. R.,
E. & T. H. R. R.,
G. R. & I. R'y,
G. T. R'y System,
Hocking Valley R'y,

Illinois Central R. R.,
L. E. A. & W. R. R.,
L. E. & W. R. R.,
L. S & M. S. R'y,
L. & N. R. R.,
L. H. & St. L. R'y,
M. C. & C. R.R.,
Mich. Central R. R.,
Mobile & Ohio R. R.,
N. Y. C. & St. L. R. R.,
N. & W. R'y,
Ohio Central Lines,
Penna. Lines,
Pere Marquette R. R.,
P. & L. E. R. R.,
P. L. & W. R. R.,
So. R'y (St. Louis Div.),
T. P. & W. R'y,
T. St. L. & W. R. R.,
Vandalia Railroad,
Wabash R. R.,
Wab. Pitts. Ter. R'y,
W. & L. E. R. R.,
Z. & W. R'y,

New England Passenger Association, covering the New England States, and embracing the following roads:

Bangor & Aroostook R. R.,
Boston & Albany R. R.,
Boston & Maine R. R.,
Canadian Pacific R'y,
Central Vermont R'y,
Eastern Steamship Co.,
Grand Trunk R'y,
Maine Central R. R.,
New York, New Haven & Hartford R. R.,
Portland & Rumford Falls R'y,
Rutland R. R.,
Quebec R. R.

Southeastern Passenger Association, from all points in territory south of the Ohio and Potomac and east of the Mississippi rivers, and embracing the following roads:

Alabama Great Southern Railroad,
Alabama & Vicksburg Railway,
Atlantic Coast Line Railroad,
Atlantic & North Carolina Company,
Atlanta, Birmingham & Atlantic Railroad,
Baltimore & Ohio Southwestern Railroad,
Blue Ridge Railway,
Central of Georgia Railway,
Charleston & Western Carolina Railway,
Cincinnati, New Orleans & Texas Pacific Railway,
Florida East Coast Railway,
Georgia Railroad,
Georgia, Florida & Alabama Railway,
Georgia Southern & Florida Railway,
Gulf & Ship Island Railroad,
Illinois Central Railroad,
Louisville & Nashville Railroad,
Macon & Birmingham Railway,
Macon, Dublin & Savanna Railroad,
Mobile & Ohio Railroad,
Nashville, Chattanooga & St. Louis Railway,
New Orleans & Northeastern Railroad,
Norfolk & Southern Railroad,
Norfolk & Western Railway,
Richmond, Fredericksburg & Potomac Railroad,
St. Louis & San Francisco Railroad,
Seaboard Air Line Railway,
Southern Railway,
Virginia & Carolina Coast Railroad,
Washington Southern Railway,
Western & Atlantic Railroad,
West Point Route (A. & W. P. R. R. and W. Ry. of Ala.),
Wrightsville & Tennille Railroad,
Yazoo & Mississippi Valley Railroad.

In case any railroad which you want to use is not included on this list advise the Secretary promptly.

OFFICERS AND COUNCIL

1905—1906

PRESIDENT

FRED W. TAYLOR.....Philadelphia, Pa.

VICE-PRESIDENTS

S. M. VAUCLAIN.....Philadelphia, Pa.
H. H. WESTINGHOUSE.....Pittsburg, Pa.
GEORGE H. BARRUS.....Boston, Mass.

Terms expire at Annual Meeting of 1906

WALTER M. MCFARLAND.....Pittsburg, Pa.
EDWARD N. TRUMP.....Syracuse, N. Y.
ROBERT C. MCKINNEY.....New York, N. Y

Terms expire at Annual Meeting of 1907

MANAGERS

GEORGE I. ROCKWOOD.....Worcester, Mass.
JOHN W. LIEB, JR.....New York, N. Y.
ASA M. MATTICE.....New York, N. Y.

Terms expire at Annual Meeting of 1906

GEO. M. BRILL.....Chicago, Ill.
FRED J. MILLER.....New York, N. Y.
RICHARD H. RICE.....Lynn, Mass.

Terms expire at Annual Meeting of 1907

WALTER LAIDLAW.....Cincinnati, O.
FRANK G. TALLMAN.....Wilmington, Del.
FREDERICK M. PRESCOTT.....Milwaukee, Wis.

Terms expire at Annual Meeting of 1908

TREASURER

WM. H. WILEY..... 43–45 East 19th St. .....New York, N. Y.

SECRETARY

PROF. F. R. HUTTON..... 12 West 31st St., New York, N. Y.

CHAIRMAN OF FINANCE COMMITTEE

E. D. MEIER

HONORARY MEMBERS

SAMUEL T. WELLMAN
EDWIN REYNOLDS
JAMES M. DODGE
AMBROSE SWASEY

JOHN R. FREEMAN

A PLAN TO PROVIDE FOR A SUPPLY OF SKILLED WORKMEN

By MAGNUS W. ALEXANDER, LYNN, MASS.
Member of the Society

1 Seven years ago, at the annual meeting of this Society, Mr. Milton P. Higgins, of Worcester, Mass., analyzing the industrial situation of that time, pointed out the significance of the lack of competent mechanics. He sounded the note of warning that unless the educational system should provide as efficiently for the training of the future skilled mechanic as it now provides for the training of those who will ultimately become leaders in industrial occupations—engineers, superintendents, and managers—there would arise a serious handicap to the development of American industries. The paper aroused much interest and provoked a helpful discussion, and the ideas set forth were echoed in the technical press and reiterated in educational circles.

2 American industries, in the meantime, have developed at a tremendous pace, and their character has undergone significant changes. Specialization has become the American watchword and the spirit of it has permeated all branches of industrial activity. While specialization in manufacture on a large scale, naturally tends to lessen the demand for all-round skilled artisans, yet on the other hand, the enormous expansion of modern industries requires a greater aggregate of skilled mechanics today than it did a decade ago; and, moreover, the degree of skill needed on account of the specializing processes and the highly complicated specializing machinery has been materially advanced.

3 Are we sufficiently supplied with mechanics who answer these present-day demands? Evidently not; otherwise the industrial training of the masses for positions at the bench and at the machine would not be such a burning question as it is today. The great amount of

To be presented at the New York Meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

discussion and printed matter on the subject, the organization of committees for the study of the problems, and the appointment of State commissions, such as the Massachusetts Commission on Industrial and Technical Education, all illustrate the vital interest of the people in this question.

4 The admonition of Mr. Higgins, it seems, has not produced the desired results; and it is incumbent upon us to inquire into the cause. Trade schools of many kinds have been started in different parts of the country, and industrial training has been further developed in the public school system, yet we find ourselves face to face again with the fact that the further expansion of the industries, especially in the mechanical trades, is endangered on account of an insufficient supply of skilled mechanics. Whom can we call to account for this state of affairs? I feel inclined to find the cause of this industrial predicament largely in the attitude of the manufacturers themselves.

5 The leaders of industries (managers and engineers) have not been sufficiently interested in this important matter; and they have not joined forces with educators in giving to the youth the very equipment which the industries demand of him. The burden has been upon the schoolmaster, who, largely confined within the four walls of the school room, has worked out his problems with pedagogical exactitude, according as he perceives the life needs of the boy; but not being himself engaged in practical industrial work, he has not been conscious of the rapidly changing forces that determine the character of industrial life. The manufacturer, in the midst of the bustle of business activity, on the other hand, is confronted day by day with the inadequacy of preparation for practical work of the great body of industrial recruits. He knows the peculiar requirements and therefore should take the initiative to a large extent in coöperating with the schoolmaster in his efforts to provide an adequate industrial training.

6 Manufacturers in general d not realize their present responsibility. Years ago, before vocational training entered into the school system, they applied themselves to the task of initiating boys into the trades; and the results achieved through their efforts seemed to meet the conditions of that time.

7 The old system of apprenticeship, once universally extant, solved the problem well. A boy was apprenticed to a journeyman who taught him a particular trade until the boy became sufficiently skilled to take and hold his place by the side of his master, who himself was an all-round artisan. The artisan of all-round skill, however, has been gradually supplanted by the specialist, skilled in one particular operation only, and consequently the old system of apprentice-

ship has practically become extinct. Under the methods of specialization, manufacturers employed larger numbers of semi-skilled and unskilled workers, and became less alert to the necessity of manning the complicated specializing machinery which came into use with men of higher skill, and of marshaling the large army of specialists with men of a more thorough all-round training and a higher industrial intelligence. This lack of foresight, however, soon showed its effect on the personnel of the working body, and called attention to the immediate necessity of providing a means for the constant renewal of the supply of skilled workers. Manufacturers found themselves confronted with the serious problem of reconciling the discrepancy between the educational equipment which the boy receives in the school, and the vocational equipment which the industries demand of him.

8 They became thoroughly aroused to the importance of this question, and looking back to the old apprenticeship system, began to revive it along changed lines to suit the new industrial conditions. Much progress has been made in this respect in the last few years, even to the extent of combining with the practical shop work theoretical education given in the factory for the purpose of producing an artisan of superior make up.

9 A significant example of this modern training by manufacturers is to be found at the Lynn Works of the General Electric Company. The undoubted success of this apprenticeship system and the novel features which it contains justify a brief outline. This system offers to boys with a grammar school education, who are at least 16 years old, an opportunity to learn a trade. Great care is exercised in selecting applicants and a further weeding out process takes place during the trial period of about a month or two—the initiation period of every apprentice. Those boys only who during the trial period give proof of native ability for the trade which they wish to learn, and who are of the general mental and normal make-up that will insure the probability of their becoming skilled artisans, as well as assistant foremen and foremen at some future time, are allowed to sign the regular apprenticeship agreement.

10 The latter provides for a service of four years at stipulated wages along a progressive scale, which is set with a view of making the boys self-supporting from the beginning—even during the trial period of service. In round figures, the compensation is $4.50 per week during the trial period and the first six months; $5.60 per week during the second six months; $6.70 per week during the second year; $7.80 per week during the third year, and $9.25 per week during the fourth

and last year. A cash bonus of $100 is paid at the termination of the course, and a "Certificate of Apprenticeship" is given to the boy at that time.

11 It is the aim of the General Electric Company to train skilled artisans in the various trades of machinist and tool maker, carpenter and pattern maker, iron, steel, and brass molder, instrument maker, and electrical worker, in such a thorough manner that the leading positions in the factory, such as assistant foremen, foremen, master mechanics, and superintendents may be filled from the ranks of graduated apprentices.

12 It is obvious that such leaders must possess some information besides the practical knowledge of the trade—an industrial intelligence, which has been admirably defined by the Massachusetts Commission on Industrial and Technical Education as: "Mental power to see beyond the task which occupies the hands for the moment to the operations which have preceded and to those which will follow it—power to take in the whole process, knowledge of material, ideas of cost, ideas of organization, business sense, and a conscience which recognizes obligation."

13 In order to gain this result, the General Electric Company has correlated with its purely trade instruction at the machine a theoretical training of an eminently practical character, designed to supplement and amplify the former, so that the boy may be able to apply in the workshop the knowledge which he gains in the schoolroom.

14 Every apprentice receives instruction in the class room for six hours a week during ten months of the year, no school instruction being given during July and August. This enables the boys to take a week's vacation in the summer without conflicting with their school work. The school rooms are close to the workshop, and the sessions are held during working hours, arranged in such a way that about one-fifth of the apprentices are at school at one time. The boys are paid the same wages during school hours that they would receive while working at the bench or at the machine. The object of this is to make them feel the importance of an education; some of the boys might otherwise be unwilling to obtain an education at the sacrifice of wages.

15 After all, we must not forget that these apprentices are only young boys of limited breadth of view, some of whom perhaps have left school because it has become drudgery, others because of the necessity, due to unfortunate circumstances, to earn a living, and still others on account of a craving desire for money making. We must

be lenient with this latter class who would prefer the hours in the shop with immediate returns in money to the hours in school with a remote promise of larger returns.

The desire for education is latent in every boy, to a smaller or larger degree, and needs only some stimulus to bring it to the surface. The payment of a compensation during school hours offers this stimulus. The company in the long run gains by this expenditure in that it develops for itself more efficient workmen.

16 The teachers in the schoolroom are men selected from the staff of engineers, draftsmen, and foremen of the General Electric Company, who are assigned for six hours a week to the work of teaching. These teachers are chosen not only for their good standing in their own profession, but also for the pedagogical qualifications which they may possess. It is obvious that these men are better acquainted with the needs of the factory, and of the industries in general, and can impart more practical instruction than educators far superior in pedagogical attainments, who have not had the advantage of the close touch with industrial activities.

17 The teachers meet fortnightly at faculty meetings to discuss the work of the school and the individualities of the pupils, for the purpose of maintaining a correlated system throughout the class rooms, and at the same time deciding upon the individual teaching that each boy requires.

18 The subjects which comprise the course of studies are: mathematics, physics, technology, and mechanical drawing. For the purpose of this paper it may not be necessary to go into the details of the interesting school program which has been described fully in articles previously written by the author of this address. It may suffice to call attention to two points, which will at once appeal to the manufacturer for their practicability.

19 The teaching is preëminently concrete, and applicable to factory conditions. The young mind can more readily grasp problems of a concrete nature. By selecting them from the actual occurrences in the factory, there is the double advantage of initiating the apprentices into the technicalities of the business, making them acquainted with the different kinds of apparatus manufactured and the different materials used; and of familiarizing them with the solution of the very problems which they will meet later on as journeymen and foremen. The figuring out of the cubical contents of a cylinder of given diameter and length is a purely mathematical problem of mental discipline in which chiefly the memory is called into play; it becomes, however, an interesting problem which demands also the

exercise of the thinking faculty if it is stated in the following manner:

"An order calls for 25 steel pins each to be $\frac{1}{2}''$ in diameter and $2''$ in length. The pins are to be cut from a rod of cold rolled steel and the tool used in the cutting-off machine will waste $\frac{1}{32}''$ of material between each two pins. How many pounds of cold rolled steel are required to fill the order?"

This is a problem which is met with in everyday factory work and involves nothing but plain multiplication and addition in its solution.

20 Study thus becomes a thing of life importance to the boy; and the teacher keeps this interest awake by presenting, wherever possible, the objects of which he speaks, and explaining their character and usefulness.

21 The second point worthy of note is the part which mechanical drafting plays in the program. This is taught, not for the purpose of developing mechanical draftsmen, but as a means of teaching the designing of tools, jigs, and fixtures needed for manufacture on a large scale. The public school system does not, and for that matter cannot, teach tool designing; and even the higher institutions of technical learning do not give due consideration to this subject, which is a very important requisite for the future mechanical engineer and shop superintendent. These, as well as the skilled mechanic, ought to possess the ability to sketch out the special tools, jigs, and fixtures that may be required from time to time for labor saving manufacture. It is not so much a question of executing fine drawings that may be used over and over again, as in the case of the manufacture of a standard article, as it is a question of sketching quickly, for the immediate use of the machinist and tool maker, a required tool which when once made is expected to remain in use for a long period. Mechanics who possess this ability of combining the work of the tool maker with the work of the tool designer have added considerably to their assets, and have, therefore, become more valuable to their employer.

22 The General Electric apprentice is being educated along these lines, for which reason a large amount of the time set aside for instruction in the schoolrooms is devoted to the teaching of tool design in the upper classes. At this stage of the course, the apprentice has had several years of practical work in the shop, and therefore understands what is wanted of him and appreciates the value of designing jigs and fixtures with a view of saving every minute in the handling of them. The apprentices are given by the teachers a machine part, for instance, or a drawing of it, with the instruction to design a jig or holder, by means of which the various holes in the part may be drilled accurately

and quickly without the necessity of laying out each hole separately and employing high skill for the operation. Each apprentice will present a different design which brings out his mechanical ingenuity, and this gives the drawing teacher a valuable help in developing the individuality of his pupils.

23 Examinations on the school work are held frequently during the year, and a final examination at the end of the course determines, to a certain extent, the standing of the apprentice, and the wages which the company considers commensurate with his value as a journeyman.

24 The other element in this consideration is the degree of skill acquired by the apprentice through his shop training. The methods of training employed are of paramount importance in developing this skill, and it is this feature in the General Electric system which is of peculiar interest. Its adoption was the outcome of a study of the prevalent weaknesses of the present systems of apprenticeship. In most of these, boys are hired by the employment department and indentured for a number of years. They are assigned to one of the shop foremen who is instructed to initiate the young recruit into the trade which he desires to learn.

25 The foreman utilizes the apprentice at first for an errand boy, and for similar duties, giving him after a time simple work at the bench, such as chiseling, and plain filing in a machine shop, shellacing and sandpapering patterns in a pattern shop, making simple cores and cleaning small castings in a foundry; or letting him assist the stockkeeper in the handling of the small tools and the stock materials. There is a certain amount of value in all this work, in that it makes the boy familiar with factory life, accustoms him to the factory atmosphere, and gives him some elementary knowledge of his trade; but after a time the knee in the curve of value is reached, and a further expenditure of time gradually becomes more and more disproportionate to the additional advantage gained. The bright and ambitious apprentice realizes when the knee in the curve is reached, and begins then to press the foreman for higher grade work, especially work at the machine. And so the apprentice step by step has to push himself forward in order to learn the different classes of work, and become acquainted with the operations on the different machines in the department. In general, the foreman is apt to be slow to give the boy the advantage of a variety of training; for if the boy is inefficient at some particular work, he will naturally be held at that work for improvement, and if he is efficient, the foreman is prone to keep the apprentice at the work for an undue length of time, in order to get the greatest commercial advantage from the boy.

26 Here lies the conflict between the purpose of the apprentice and the foreman. The boy comes for a training; he wants to secure all possible information in the shortest time, and therefore desires a variety of work in the department, and an opportunity to work in all departments of the factory. The foreman, on the other hand, representing the company, strives for economy, for cheapness of production, and he can better further his ends by keeping the apprentice at one class of work and in one department for a long time. Few foremen combine with this legitimate care for their own interests the proper appreciation of the boy's object. Of course we must acknowledge that there is a certain advantage in obliging the boy to forge ahead for himself against the difficulties which have been enumerated; for in this way the weak and undeserving will fall by the wayside and the fittest only will survive. Over against this, however, we must admit that many apprentices who succumb to this unequal struggle would under more advantageous conditions come out victorious.

27 Realizing this, some manufacturers have employed a suitable man to look after the apprentices during the whole time of their course and to assist the foremen in giving the boys an adequate industrial training. This overseer, as we may call him, jointly represents the interests of the employer and the apprentices; and to the extent to which he possesses breadth of view he will fulfill this dual function to the advantage of both. In many instances his interest in the boys will lead him to inaugurate evening classes for the study of mechanical drawing, mechanics, and kindred subjects, and even perhaps to influence them in their leisure hours.

28 A system of apprenticeship along these lines is a decided step forward in the right direction, but it still contains one important defect in common with the system first outlined.

29 In either case the apprentice is the pupil of whomever happens to be foreman, assistant foreman, or leading journeyman in the department to which he has been assigned. These men have been selected for their skill, and not on account of any special fitness that they may have for instructing boys. It is well known that few people in whatever walk of life, with the exception of professional teachers, are qualified to impart information in a satisfactory manner, though they may themselves possess this knowledge and may well be able to apply it to their work.

30 The drawback under which the boy thus labors is often further intensified by the productive requirements in commercial manufacturing establishments. Some departments, for instance, may have only

a small amount of work on hand and of such a nature that it will not add to the boy's skill and knowledge; while others may be crowded with work of an instructive and interesting character. The boy who happens to be assigned to the first department is, therefore, put at a decided disadvantage over the apprentice in the other department where productive conditions offer a splendid opportunity for his further advancement. The realization of these weaknesses in the systems of apprenticeship leads to the remedy that should be applied, which is to equalize the opportunities of all apprentices, and to afford them the most expert instruction in the practical work of the trade, especially during the first part of their course, for a solid or faulty foundation determines the strength or weakness of the whole structure of achievement. The General Electric Company has proved the validity of this remedy.

31 Four years ago it started as a special department devoted entirely to the preliminary, practical training of the apprentices a small shop in the big factory organization, directly under the control of the man in charge of apprentices. Beginning in a small way, this "Apprentice Training Room" has grown in size and equipment until today it covers an area of about 10,000 square feet with a tool equipment of 105 representative machines. There are 20 drill presses of various sizes, 4 speed lathes, 1 pulley lathe, 1 turret lathe, and 44 engine lathes, some of which are belt driven, while most of them have individual motor drives. These engines lathes vary in sizes from 12 inch swing and 5 foot bed to 20 inch swing and 8 foot bed, and are fitted up partly with plain rest or rise and fall carriage or compound rest and partly with taper attachment suitable for tool work. There are also two 24 inch planers, nine 15 inch shapers, one 42 inch vertical boring mill, two plain and two universal horizontal milling machines, one vertical milling machine, one centering machine, one spliner, one wet grinder, two universal grinders, one surface grinder, four tool grinders, one hack saw, two arbor presses, one bench watchmaker's lathe, besides a number of small electric bench drills, buffing and polishing motors. Then there are, of course, the necessary small tools, such as drills, taps, reamers, chucks, and arbors, besides 40 vises.

32 Most of the machines are of the latest and most improved type, while some of them are second-hand tools, a few of which have even been rescued from the scrap heap. There is a twofold purpose in the use of old machines—the economic and the educational; it prevents the abuse and injury of high priced modern machinery, which is apt to occur with boys who have not had experience in the handling of machines, and it affords an opportunity for repairing ma-

chine tools, which is undoubtedly the best training that can be given to a future mechanic, since it develops the ability to do things, thoughtfulness, and self-reliance. Some of the old lathes have thus been provided with new gears, the spindles have been turned down, the bearings rebabbitted, or some special attachments have been added until they have been made practically as useful as some of the expensive modern lathes. A stockroom of suitable size occupies one corner of the training room and is conducted in the same manner as a stockroom in any well managed manufacturing establishment. This equipment is large enough to instruct about 125 boys at one time. Usually about 15 of these are applicants serving their trial period, while the rest are regularly indentured apprentices on their first and second year of service.

33 The man who has charge of this training room is an ingenious mechanician, who has himself served an apprenticeship, has had charge of men and work, possesses the ability and patience to instruct beginners, and is peculiarly adapted to this kind of work. He interviews all applicants, and with a keen insight selects those who are to be admitted to the trial service. This gives him an opportunity to study carefully the boy's mental and moral make-up and his native ability for the chosen trade. A painstaking and encouraging attitude toward one, a severe and almost threatening arraignment of the other will bring out very often latent qualities that might not come to the surface except for this individual treatment. The careful selection of those who are to be admitted to full apprenticeship is a very important function of the shop instructor, in that it determines the personnel of the apprenticeship system. Under the stipulations of the contract, the General Electric Company has a right to terminate the service of any apprentice at any time for good cause, such as improper behavior or inefficiency of work; yet in accepting the boy for regular apprenticeship and indenturing him, the company has assumed a moral obligation for the development of the apprentice which it cannot very often cancel without forfeiting the faith and confidence of the public.

34 The instructor initiates the apprentices into the trade and lays the foundation for their future skill and efficiency. It is his duty, wherever possible, to inaugurate with the apprentices labor saving methods of manufacture, and to make and use labor-saving devices which thereafter will be accepted by the other factory departments. He can without difficulty develop the highest practical cutting speeds and thus set a standard in this respect to the whole factory organization. The training room stands for the best and most efficient methods, and is not hampered in its development along these lines by a

hostile attitude which may be encountered in factory departments on the part of regular workmen, which is usually due to ignorance or misunderstanding of the true conditions. The shop instructor has two assistants, this small number being made possible by carrying out the policy of utilizing most of the apprentices themselves for assistant instructors. After an apprentice has learned thoroughly a certain operation, turning of pulleys, for instance, he is usually required to break in a new apprentice on this kind of work before he himself is taught another operation, boring, for example, by an older apprentice who has already learned this operation.

35 In this manner, the apprentice is pupil today and teacher tomorrow, then pupil again and teacher once more. The advantage of this policy is obvious. It develops early in the apprentice the faculty to instruct, and keeps him wide-awake in his work. The young master will put forth his best efforts to impress the young recruit with his own achievements and the latter will often not hesitate to ask his boy teacher questions that he may not, out of false pride, ask the regular instructor. Couples of boys may, therefore, be seen in the training room almost every day. A study of their instructive and receptive efforts is quite interesting. Some of the apprentices are required to spend a few weeks in the stockroom and learn stockroom methods, or act as clerks to the shop instructor in order to become acquainted with the clerical duties of a shop foreman; the making out of time cards and reports, the ordering of raw materials, and the shipping of finished goods. The object of all this training is to make real workmen, and this can be achieved only by carrying on real work. All production in the training room, therefore, is of a commercial value.

36 The General Electric training room makes cast iron pulleys of various sizes and design, clutch pulleys and flange couplings, small and large parts of regularly manufactured machinery instructive in the teaching of turning and boring, drilling and grinding, planing and shaping, milling and slotting; it manufactures shafts for fan motors and power motors, and spindles for various purposes, and finally produces not only the special tools, jigs, and fixtures needed for its own use, but also many of those required for other factory departments. The psychological value of commercial work is of great importance; it takes the boy out of the sphere of laboratory work into that of industrial life; it clinches the boy's interest, inasmuch as it makes him realize that the product of his work is to be a part of some useful machine, rather than a plaything or an object of exhibition in some show case. The possibilities of apprentices under proper instruction, having the

right interest in their work, are remarkable. Almost every week brings new surprises in the General Electric training room at Lynn.

37 A training room similar to the one just described for machinist apprentices is maintained for the pattern-maker apprentices. This has a less complete equipment of its kind, however, on account of the smaller number of boys indentured for this trade. This condition may be improved at some future time by enlarging the machinist training room through the addition of a suitable pattern shop equipment.

38 The General Electric Company has only a few foundry apprentices who are instructed in the regular foundry. It stands to reason, however, that a sufficiently large number of foundry apprentices would justify the installation of a foundry training room.

39 A separate building with foundry, pattern-maker, and machinist training rooms, with the class rooms on the top floor, would be the ideal trade school in the factory.

40 After the apprentices have spent from $1\frac{1}{2}$ to $2\frac{1}{2}$ years in the training room, according to their individual ability, they are transferred to factory departments where they serve a post-graduate course for the remaining part of their apprenticeship. They learn here accuracy and speed on a greater variety of work, and have an opportunity to specialize in die-making or tool-making, or laying out machine work for which they are best suited. The apprentices are now under the charge and discipline of the respective shop foremen and have to all intents and purposes taken their places beside their shop mates, although they still attend the apprentice school. The shop instructor, however, retains his interest in the apprentice whom he may transfer from one department to another, either at the request of the foreman or the apprentice, or whom he may even take back temporarily to the training room, either for the good of the service or for the rectification of some defect that the boy may have developed in his work. If a disagreement between a foreman and an apprentice arises, the shop instructor acts as a mediator. He considers the apprentices as his boys and looks upon them in that light even after they have become journeymen. He passes final judgment on the apprentice when he determines the standing to be recorded in his "Certificate of Apprenticeship."

41 The General Electric Company encourages all graduated apprentices to remain in its service and, as previously stated, hopes that in due time most of the assistant foremen and foremen in the factory will be graduated apprentices. Some of those who have shown a special ability in their drawing work in the class room are appointed as tool designers in the drawing office, where their combined knowl-

edge of tool making and practical tool designing puts them far ahead, in this line of work, of even college educated but not shop trained draftsmen.

42 Up to this date 462 boys have been admitted to the trial service and 293 of these have been indentured as apprentices. Of the latter 37 have terminated their contract with the consent of the company on account of sickness, removal of the family from town, or other good reasons; 35 have broken their contract by seeking other employment during their apprenticeship, and 21 have been discharged for good reason. Of the remainder, 29 have graduated; 171 are still on the apprenticeship course, and 37 are serving their trial period. Of the graduates 24 are still in the employment of the General Electric Company at Lynn, and most of those who have sought other employment will sooner or later return to their alma mater.

43 Very often the graduated apprentice with the hundred dollars cash in his pocket determines to seek employment in some other place in order "to see something of the world," as he puts it. Such desires should not altogether he discouraged; it will often do a boy a great deal of good to get among strangers, and the rubbing up against the world will take off the rough corners, and round him out into a fuller and better man.

44 The success of the General Electric plan is not peculiar to the conditions which exist there; it can be applied in a more or less modified form to any manufacturing concern of suitable size. Its establishment should be encouraged, since it benefits alike the apprentice who obtains an excellent industrial training and the employer who not only develops efficient men for himself, but does it at no financial sacrifice, on account of useful work performed in the training room. The picture of a well equipped training room suggests another thought in carrying out the plan to provide for a constant supply of skilled workmen. It has often been pointed out that our public school buildings with their expensive equipment ought to be used for more than six hours a day, five days in the week and forty weeks in the year. This contention has led to the social utilization of the schools for evening classes, public lectures, parents' associations and neighborhood clubs. May we not begin to point to the uneconomic condition under which large factory buildings with their costly equipment are left idle from six at night until seven in the morning, and in many cases from noon on Saturdays? Cannot these factories be utilized during these idle hours for industrial extension work for the benefit of the people without expense to the employer? The training room affords an excellent opportunity for a beginning. It is

a self-contained department with a full equipment necessary to learn the machinist's trade in all its principal branches; and, as a rule, work left in the machine at the close of the regular factory hours is not of as expensive character as may be found in ordinary machine shops, where the removal of it from the machine may seriously interfere with economic and quick production.

45 This training room could, therefore, be opened from seven to ten at night, and on Saturday afternoons, to those employés of the company who desire to learn the machinist's trade or some part of it. There are undoubtedly many ambitious workingmen, who on account of lack of education and skill or through thoughtlessness in their younger days are now occupied with unskilled labor with no apparent chance of rising either in position or in wages. They may be anxious to improve their condition by learning to do work on a lathe, planer, shaper or boring mill, or on several of these machines. What opportunities have such men now for gratifying their ambition? Some through perseverance may persuade their foremen to put them at one of these machines where they would receive more or less superficial instruction. They have there a chance to earn somewhat increased wages, especially if they become experts on one machine. Further advancement is probably precluded.

46 Some workmen are fortunate enough to live in one of the few cities in which evening trade schools have been established. But what about the great majority of unskilled workers who could acquire some skill, and thus rise from a lower to a higher industrial efficiency, if they had an opportunity to be instructed in practical work during their leisure hours? Let these men in the factory come together in small classes for learning to do such work as their ambition dictates, and utilize the training room for three evenings a week. The shop instructor of the apprentices with able assistants may well take charge of this evening training for which he, of course, would receive extra compensation. The instruction should be thorough in regard to the work on the machine as well as the machine itself, and those only who satisfy the shop instructor of their ability should be allowed to remain. Fairly good lathe, shaper, planer, or borings mill hands can be turned out after six to nine months of evening instruction, and universal milling machine operators in about a year's time. Those who satisfactorily complete a special course should be given a Certificate of Special Apprenticeship and for each subsequent additional course completed an additional certificate should be issued.

47 The work in the evening classes should consist of regular factory work and the value of properly finished pieces to the company

would probably offset the expense of heat, light, and power, wear and tear of machinery and small tools, and spoiled material. A small tuition fee of perhaps three dollars a month would pay for the salary of the instructor and his assistants.

48 This is only a brief outline of a plan which can be worked out as an excellent investment for the workman who thus increases his earning capacity, and for the employer who adds to his supply of skilled workers. One can readily perceive how many a workman through close application to several years of practical evening instruction may develop into a skilled mechanic even though he has not had the advantage of an apprenticeship training. The possibilities of the one are as great as those of the other.

49 We have so far considered ways and means by which an employer may provide for a constant supply of skilled workmen for his own benefit. What can be done by the individual for himself can undoubtedly be accomplished for the industries in general by the right man and the right methods. It would necessitate the separation of the training room from the individual factory, and its establishment as an independent institution in a place where its work could be of benefit to the industries of the locality. The day course would have to be elaborated upon in order to include what has been previously termed the "post-graduate course in the factory," so that the apprentices may go from here directly into the industries as full fledged journeymen. There are advantages and disadvantages in the independent school shop as contrasted with the factory training room.

50 The school shop will be able to attract a desirable class of boys who would gladly enlist in an institution of a vocational character, but would not care to enter upon an apprenticeship course in a factory. The lack of respect for mechanical work on the part of the American youth is responsible for this state of affairs. There is the other marked advantage of having an institution that is centered on one interest—the training of efficient workmen. On the other hand, the school shop has not the amount and variety of work right at hand which obviously the factory training room can command at all times. Able business management, however, will overcome this difficulty so much the more readily as manufacturers have a selfish object in furthering the aims of the school shop; the latter must also provide for the design and manufacture of an easily salable article that can, therefore, be produced for stock at such time when other commercial work cannot be obtained in sufficient quantity.

51 The standard of the school shop must be of the highest, so that it may commend itself through the excellency of its graduates, both in

the day and evening classes, to employers, employés, and the public in general. A high standard must be maintained in the practical shop training as well as in the purely educational work. The latter may be conducted along the lines worked out by the General Electric Company, or it may be placed under the charge of the public school authorities, who, after all, are responsible for giving the boys the training which they need to make them self-supporting members of the community. The State would also infuse a sufficient amount of the cultural element to develop the boy at the same time into a man and a law-abiding citizen. This latter plan, however, could only be carried out if the school authorities of the town in which the school shop is located would consent to the establishment of a special school course, offered at such times of the day when a part of the apprentices could be spared from the school shop. The special school program would have to be worked out so as to meet the demands of the industries and would have to be taught by properly qualified teachers whom we might term, "industrial instructors." Until such conditions prevail, the school shop will have to look after its own educational work. Proper conditions may be brought about quickly in Massachusetts, for instance, through the coöperation of the management of the school shop and the Massachusetts Commission on Industrial and Technical Education. The Commission was appointed recently for the purpose of studying the industrial needs of the State and of establishing industrial courses and trade schools that will answer these needs. The school shop could serve the Commission as a laboratory, in which they could work out jointly with the manager of the same an adequate industrial training of the boys.

52 Under this combination the school shop may be run as a commercial, profit making establishment without any injury to the educational development of the apprentices but with some advantages which an educational institution of even a vocational character cannot offer.

53 In this address I hope I have stimulated interest among the manufacturers in the subject of providing for a constant supply of skilled workmen, and trust I have indicated a possible plan that will readily lend itself to the solution of the problem under existing conditions.

TEST OF A ROTARY PUMP

By W. B. GREGORY, NEW ORLEANS, LA.
Member of the Society

1 Four years ago a paper, entitled "Rotary Pumps," was contributed to this Society by Mr. John T. Wilkin. This paper left very little to be said concerning the details of construction of the two lobed, cycloidal pump. The largest pumps of this class have been built in response to a demand in the rice irrigation districts of Louisiana and Texas, where there are pumping plants having an aggregate capacity of 1,100,000 gallons per minute. The development of these large irrigation plants has taken place in the last ten years. The annual statement of the expenses of operation and especially of the fuel bills, have shown the plants using rotary pumps to be very economical. This is due in part to the direct connected compound condensing Corliss engines that are often used to drive the pumps and in no small measure to the efficiency of the pumps themselves.

2 In the paper referred to above, this statement was made, "The writer has taken many indicator cards from engines operating rotary pumps and finds the combined efficiency of the pump and engine to be 80 to 84 per cent." Some engineers were skeptical in regard to the truth of this statement, as the efficiency stated is the product of two efficiencies, viz: that of the engine and that of the pump. Experience with centrifugal pumps had taught that a pump efficiency of nearly 90 per cent was too good to be true. The writer was among the doubting ones and, for this reason, gladly welcomed an opportunity, offered during the summer of 1905, to test a pumping plant using rotary pumps. The plant is located near Abbeville, La., is used to furnish water for rice irrigation, and is the property of the Abbeville Canal Company.

3 The results of this test form a part of the report of the U. S. Department of Agriculture, Office of Experiment Stations, Irrigation and Drainage Investigations. The height through which the water

To be presented at the New York Meeting (December, 1906), of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

was lifted was about 15.5 feet; the engine, a tandem compound condensing Corliss, dimensions 14 x 28 x 42 inches, indicating 155.6 horse power. The amount of water pumped averaged 72.13 cubic feet per second. The average mechanical efficiency of pump and engine was 81.77 per cent.

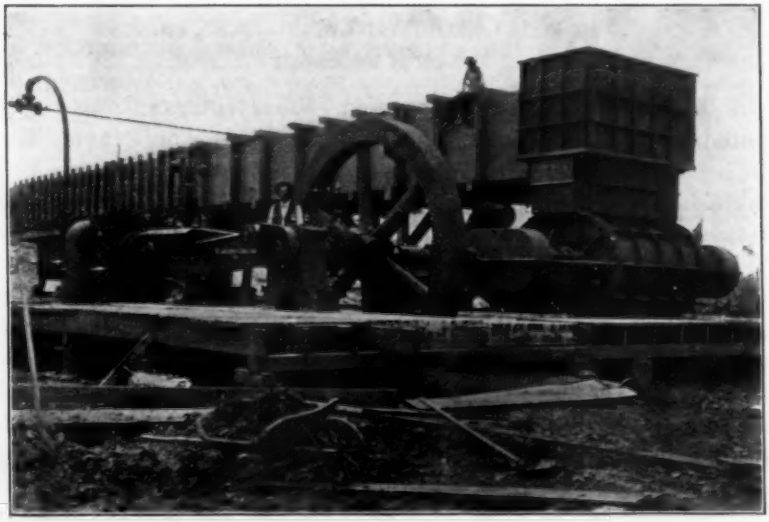

FIG. 1 ONE OF THE TWO UNITS OF THE ABBEVILLE PUMPING PLANT

4 The Neches Canal Company furnished water to irrigate approximately 24,000 acres of rice during the season of 1906. The main pumping plant is located on the bank of Pine Island Bayou, a tributary of the Neches River, about six miles north of Beaumont, Texas. At this plant the water is elevated from 31 to 35 feet, depending on the stage of water in the bayou. A canal, with levees 150 feet between crowns, conducts the water from the main pumping plant to the relift plant about two miles distant, where it is again elevated 10 feet. Beyond the relift plant there are 23 miles of main canal and 18 miles of laterals through which the water is distributed to the rice fields. The system has been operated for four seasons. The cost of pumping plants, canals, and laterals was $500,000.

5 The tests described in this paper were made on August 8 and 9, 1906. The plant tested was the first lift or main pumping plant of the Neches Canal Company. On the first day, one-half of the plant was operated while on the second day the entire plant was run.

DESCRIPTION OF THE PLANT

6 The boiler equipment of this plant consists of two water tube boilers, built by the Erie City Iron Works, each of 400 nominal horse power, having 3675 square feet of heating surface. Each boiler has two drums 42 inches in diameter, 21 feet in length, and 180 four inch tubes, 18 feet long. A breeching 72 inches in diameter, conducts the burned gases to a steel stack of the same diameter, resting on a brick base; the length of stack is 90 feet and the total height above furnace, about 115 feet.

7 Steam is conducted from the boilers by separate pipes to a main which supplies the various engines. By means of a stop valve, the two halves of the plant may be separated and boiler No. 1 used to supply steam to engines Nos. 1 and 2, and boiler No. 2, used with engines Nos. 3 and 4. There are steam separators above each engine.

8 The fuel used was crude petroleum, it was fed to the furnaces by gravity, as the storage tanks are located at a height considerably above that of the furnaces. Steam is used to atomize the oil.

9 There are four tandem compound condensing Hamilton Corliss engines, dimensions, 18 x 36 x 48 inches; piston rods $4\frac{5}{8}$ and $3\frac{1}{4}$ inches in diameter. Each engine is directly connected to a rotary pump by means of a flexible coupling. Keys of babbitt metal are used in the couplings; these keys are made strong enough to carry the load, but will shear in case a piece of wood or other obstacle gets into the pumps.

10 The pumps are two lobed, cycloidal, of 39 inches pitch diameter. The impellers are $58\frac{1}{2}$ inches in length; the displacement is 605 gallons per revolution. The bearings are 11 inches in diameter by 30 inches in length. The details of construction may be seen in Figs. 2 and 3.

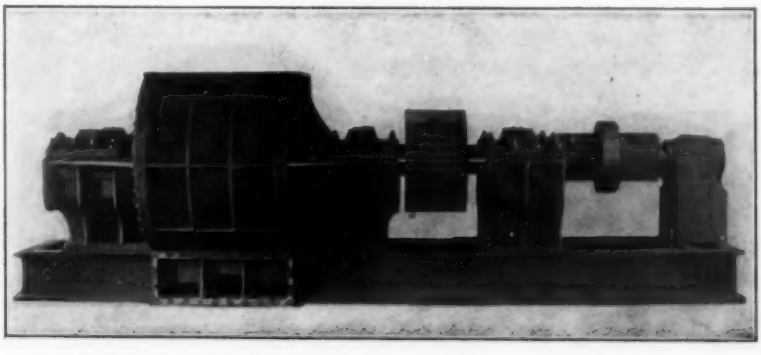

FIG. 2 ONE OF THE PUMPS OF MAIN PUMPING PLANT, NECHES CANAL CO.

11 Two vertical vacuum pumps are used, one for engines Nos. 1, and 2, and another for engines Nos. 3 and 4; they are of the jet type. The dimensions of these pumps are 12 x 28 x 18 inches; the number of double strokes per minute, about 35.

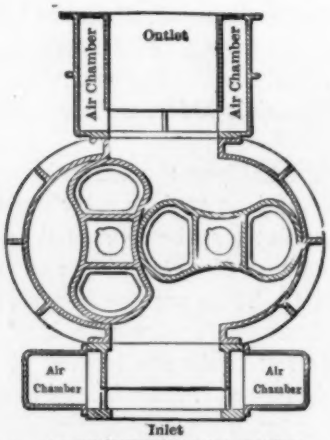

FIG. 3 CROSS-SECTION OF PUMPS

12 Two direct acting steam pumps are used for boiler feeders, when the entire plant is in operation; they are outside packed, double-

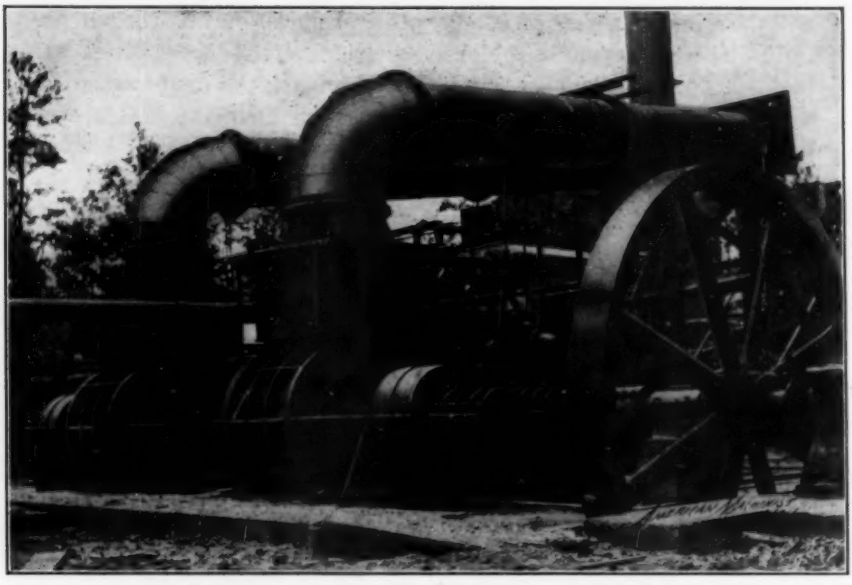

FIG. 4 PUMPING PLANT IN PROCESS OF ERECTION

acting, having dimensions 15 x 8 x 12 inches. The usual number of double strokes is about 21 per minute.

13 There are two No. 7 Cochrane heaters; each receives the exhaust from one vacuum pump and one feed pump.

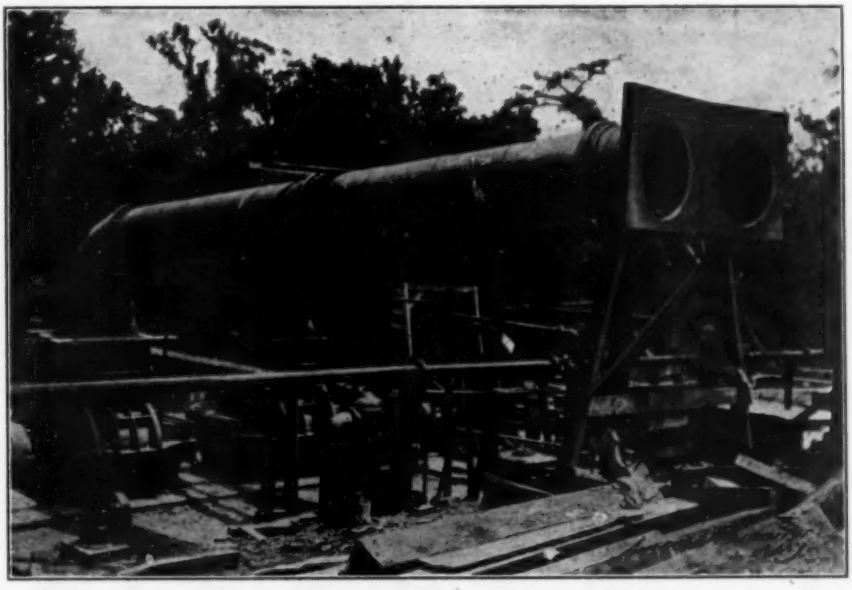

FIG. 5 PUMPING PLANT IN PROCESS OF ERECTION

14 Two views of the plant in process of erection are given in Figs. 4 and 5; the magnitude of the plant may be gaged by means of the discharge pipes which are 48 inches in diameter. A cross-section of the plant showing the location of the engines, the suction and discharge pipes, and the connection of the latter with the steel flume, which conducts the water to the canal, is shown in Fig. 6.

DESCRIPTION OF TESTS

15 The object of the tests was to determine the various efficiencies of the plant, the mechanical efficiency of pumps and engines, and the cost of operating. Great care was used in measuring the input of energy in the form of fuel oil and the output in the form of useful water horse power.

16 On August 8, engines and pumps Nos. 3 and 4 were run. Steam was furnished by boiler No. 2. The stop valve in the steam

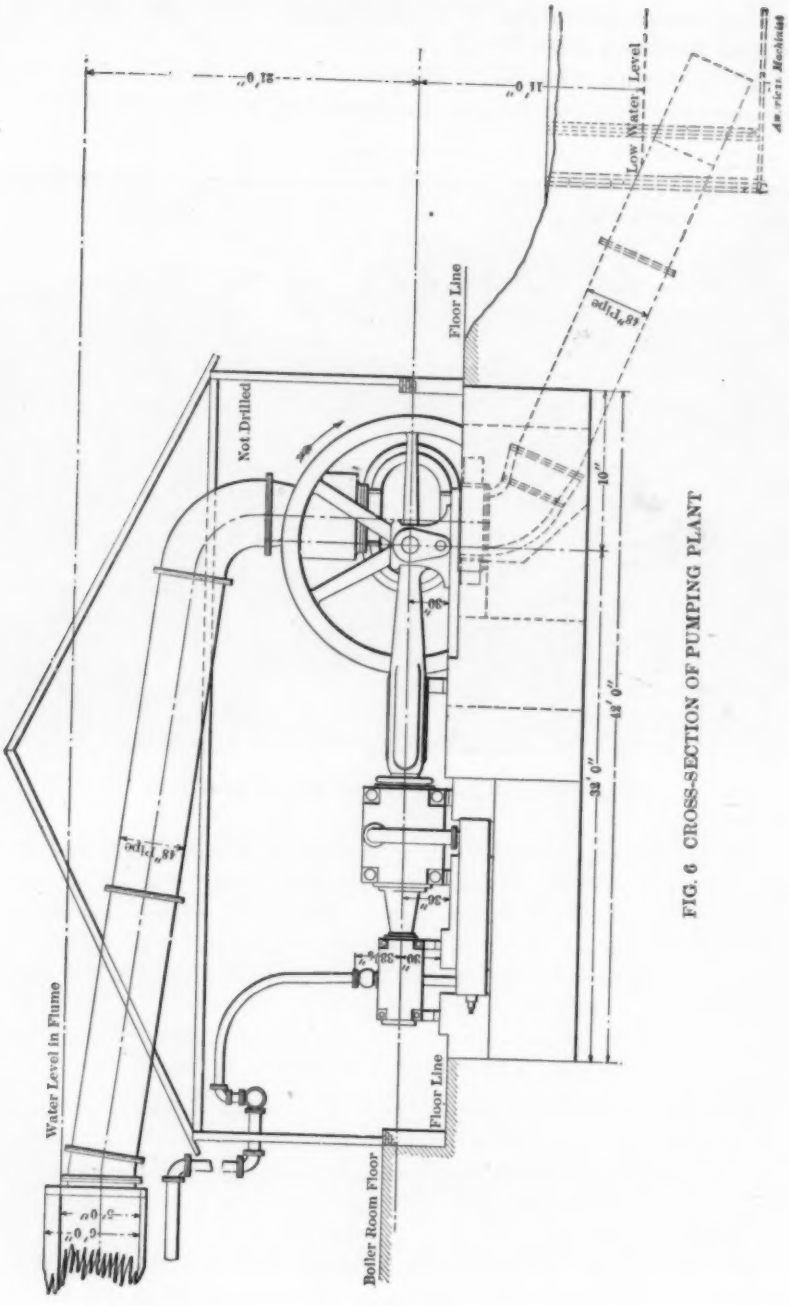

FIG. 6 CROSS-SECTION OF PUMPING PLANT

main between the two halves of the plant was closed. There was some leakage at this valve and also at the two blow-off valves of the boiler used. Leakage of air through boiler No. 1, into the breeching caused another loss.

17 A second test was run on August 9, 1906, with the entire plant in operation. During this test there was no leakage from the blow-off pipes of either boiler. The drain pipes from the steam separators were closed on both days; the other leaks from the steam main were small and no attempt was made to measure them.

18 On the first day, continuous counters on engines Nos. 3 and 4 were read at intervals of five minutes; headings for 15 minute intervals are given in the general log. For computing i.h.p. the revolutions were taken from the five minute interval during which the cards were taken. Indicator cards were taken every half hour.

19 The discharge from the two pumps was carefully measured in flume No. 2 by means that will be described later. The theoretic displacement of pumps and their actual discharge were compared, and the mechanical efficiency of engines and pumps determined.

20 Observations were also taken, at half hour intervals, of boiler pressure, the temperatures of feed water, calorimeter, water pumped, air, and fuel oil. A draft gage, connected to an air valve in the breeching, gave the draft in inches of water.

21 Fuel oil was carefully measured in a calibrated barrel and its specific gravity observed throughout the test by means of a hydrometer.

22 The amount of boiler feed water was measured by means of a weir.

23 On the second day when the whole plant was in operation, the total water discharged from both flumes was measured; at intervals of 15 minutes the water measurements were made so that they were repeated in each flume at half hour intervals.

24 The head was carefully measured in the same manner as on the previous day, the fuel oil was carefully measured, and the steam pressure was held exactly as on the first day. In this way the total useful work done and the amount of fuel required to operate the entire plant were measured under conditions exactly corresponding to those of the previous day.

INSTRUMENTS USED

25 Feed water was measured only during the test of August 8. As the tests were to represent as nearly as possible the conditions of ordinary operation, it was desirable to use the heaters, the water

level in which was only about two feet above the center of the feed pump. The high temperature of the feed water made it necessary to have the water flow by gravity to the pump. The pipe connections were short and the measurement of feed water in calibrated tanks could only be accomplished by the aid of an extra pump, or by taking cold water from the flume. A trapesoidal weir, six inches in width, was introduced between the heater and pump by slight changes in the piping. The discharge from the weir was into a barrel, connected to the suction of the feed pump. The height of the water above the sill of the weir was measured by an accurate hook gage. In this way the plant was operated under normal conditions and the water measured with considerable accuracy. The weir had been previously calibrated in the Hydraulic Laboratory of Tulane University of Louisiana, and its constant determined. It is believed that the error involved does not exceed 2 per cent and that it is probably only half that amount.

26 By this method all the water fed to the boiler was measured; the steam generated was used by main engines, by vacuum and feed pumps and for atomizing the fuel oil.

27 The quality of steam was obtained by means of a throttling calorimeter in the vertical pipe coming from the boiler, a short distance above its junction with the horizontal main.

28 The conditions of the boiler test were extremely uniform; the water level changed very little, and the rate at which water was supplied to the boiler was not varied throughout the test. Steam pressure, quality of steam and the temperature of feed did not vary perceptibly.

29 The boiler pressure and the vacuum were read by means of calibrated gages. The error of the thermometer used in the calorimeter was known and the correction applied.

30 Two Crosby indicators were used on engine No. 3, and two Thompson indicators on engine No. 4. All were supplied with wheel reducing motions. Each cylinder of each engine was fitted with three way cocks; on the high pressure cylinders 80 lb. springs were used, while 20 lb. springs were used on the low. The springs were calibrated after the test and corrections applied where necessary.

31 The barrel in which fuel oil was measured was calibrated by means of an accurate spring balance.

32 Samples of the fuel oil were taken from time to time during the test, and later a careful determination of the heat value was made at Tulane University of Louisiana. The heat units per pound were found to be 18,790; the amount of water present in the oil was 2 per cent. The oil was from the Jennings, Louisiana, field.

WATER MEASUREMENTS

33 The height through which the water was lifted was obtained by measuring down from bench marks on the suction side of the pumps to the water level in the suction flume, and again from a bench mark on the discharge side to the level of water in the discharge flume. The head was extremely constant. All linear measurements taken by means of a tape were corrected by comparison with a steel tape.

34 The discharge of pumps Nos. 3 and 4, is into a common flume, built of ¼ inch steel, having an inside width of 8.71 feet; the depth of water in the flume was obtained by measuring the distance from an angle iron across the top to the bottom of the flume and subtracting the distance from the angle iron to the surface of the water. The depth varied little from 4.17 feet throughout the test; each time six observations were taken and averaged.

35 Two instruments were used alternately to determine the mean velocity—a current meter and a Pitot tube. The current meter is a Gurley No. 31, the property of the Office of Experiment Stations, U. S. Department of Agriculture. It had not been used since it was rated and was in an excellent condition. The stop watch ordinarily used with the meter was found to be broken just as the test was started so a common watch was used throughout. The confusion of counting revolutions of the current meter by means of a buzzer and at the same time keeping accurate tally of the time without a stop watch, was accountable for the failure to get results at 6 p. m. and again at 6.30 p. m. when the operator was fatigued by several hours of hard work in a broiling sun.

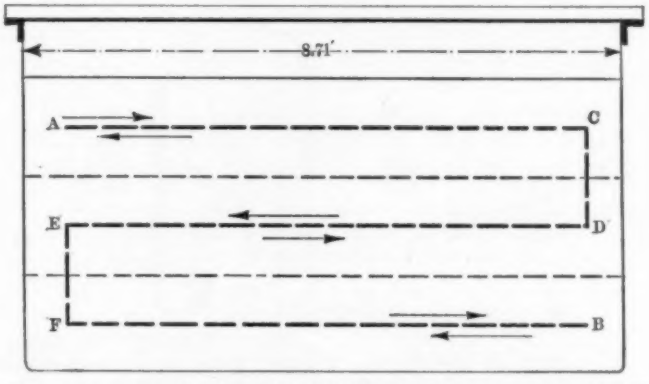

FIG. 7 CROSS-SECTION OF FLUME SHOWING METHOD OF MAKING A TRAVERSE WITH CURRENT METER

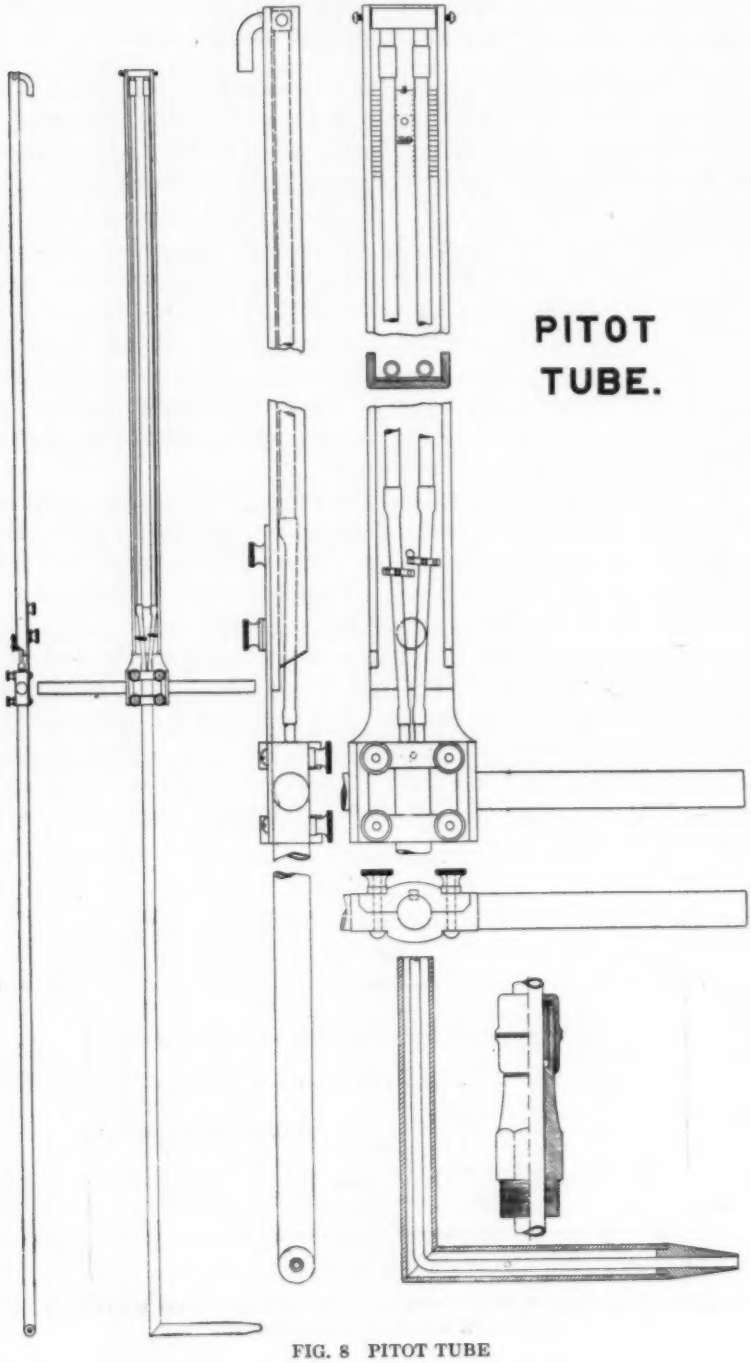

FIG. 8 PITOT TUBE

36 The method of making a traverse with the current meter is clearly shown in Fig. 7. The meter was lowered to the starting point *A* and slowly moved along the dotted path to *B* and then back again to the starting point. The movement was so slow that no correction for the component of side motion was required, as the time was usually about five minutes. Between the points *C* and *D* and also between *E* and *F* the meter was moved rapidly in order to avoid the error due to the slow velocities near the sides of the flume.

37 The Pitot tube used is shown in Fig. 8. This instrument is the property of Tulane University of Louisiana and was designed by the writer. The constant of the instrument is unity in the formula,

$$v = \sqrt{2gh}$$

It has proved to be a very accurate and reliable instrument; experience has shown that in both these qualities, it is the equal of the current meter in open channel work where the velocity is four feet or more per second. The method of using the Pitot tube is illustrated in Fig. 9. The cross-section of the flume was divided into eighteen rectangles, approximately squares, and the point of the instrument held facing the current at the center of these rectangles; the arithmetical mean of the velocities found was used as the mean velocity of the water in the flume

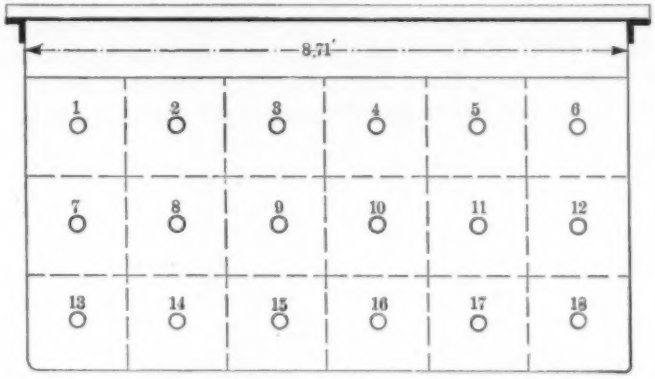

FIG. 9 CROSS-SECTION OF FLUME SHOWING POINTS WHERE VELOCITY WAS OBSERVED BY MEANS OF THE PITOT TUBE

ACCURACY OF WATER MEASUREMENTS

38 The general log shows the percentage difference between the discharge and the displacement of the pumps, in terms of the latter,

for separate observations; this "slip" is sometimes positive and sometimes negative. The displacement was computed from the five minute observations of the revolution counters; while small errors will occur in individual cases they will balance each other in a series of observations. The accuracy of results can therefore best be judged from average results; in this way a comparison can also be made between the results obtained by the two instruments.

39 The average of all readings taken with the current meter gives a discharge of 152.99 cubic feet per second, while the average displacement of the pump for corresponding readings averages 152.90. The average of all readings of discharge obtained by means of the Pitot tube, gives 152.79 cubic feet per second; the average displacement for corresponding readings is 152.92 The agreement in both cases is remarkable and can lead to but one conclusion, viz: that the discharge of the pumps is equal to their displacement. After making the above comparison and reaching the conclusion stated, the useful horse power for the test of August 8 was computed on the basis of displacement instead of discharge; this makes the results a little more regular and does not affect average final results. Measured discharge was, of course, used in computing the results of the test of the entire plant on August 9.

40 The writer believes these results to be as accurate as could be obtained with a weir.

41 Acknowledgment is hereby made to Mr. J. F. Taddiken, Jr., at present in the employ of the Sewerage and Water Board of New Orleans; to Mr H. P. Porter of the Connersville Blower Company; to Mr. C. O. Brookshire, Chief Engineer of the Neches Canal Company, and to his corps of assistants for valuable aid during the tests.

TEST OF MAIN PUMPING PLANT, NECHES CANAL

TEST OF ENGINES AND PUMPS, NOS. 3 AND 4, AUGUS

TIME	PRESSURES			VACUUM GAGE	CONTINUOUS COUNTERS ENGINES		R. P. M. ENGINES		INDICATED HORSE POWER											GRAND TOTAL
									ENGINE NO. 3					ENGINE NO. 4						
		RECEIVERS							HIGH		LOW			HIGH		LOW				
	BOILER	NO. 3	NO. 4		NO. 3	NO. 4	NO. 3	NO. 4	H	C	H	C	TOTAL	H	C	H	C	TOTAL		
1:30	140			23.9	0888	9254	55.6	56.6												
1:45					1702	0119	53.6	58.2	95.8	95.0	65.2	57.9	313.9	107.8	104.0	63.2	59.6	334.6		648.5
2:00	140			23.9	2532	0994	55.0	55.6												
2:15					3357	1869	55.5	58.3												
2:30	140	8	9	23.9	4183	2744	55.2	58.4	98.6	97.8	67.1	59.4	322.9	109.9	103.2	65.4	59.9	336.4		659.3
2:45					5009	3620	55.1	58.6												
3:00	140	9	10	23.9	5834	4499	55.4	58.4	97.9	94.5	74.2	62.5	329.1	101.7	100.0	68.1	61.0	330.8		659.9
3:15					6662	5378	55.2	58.6												
3:30	140	10	9.2	23.9	7489	6256	54.9	58.4	94.3	92.7	69.9	62.6	319.5	105.2	101.0	69.5	62.3	338.0		657.5
3:45					8314	7134	55.1	58.6												
4:00	140	9.4	9.7	23.9	9140	8012	54.8	58.4	94.9	94.1	70.1	62.8	321.9	103.5	100.0	69.7	62.0	335.2		657.1
4:15					9965	8889	55.4	56.4												
4:30	140	8	10	23.9	0790	9768	55.0	58.4	95.4	93.9	67.0	59.9	316.2	105.3	100.8	69.2	62.2	337.5		653.7
4:45					1616	0646	55.2	58.8												
5:00	140	9	9.7	23.9	2443	1526	55.0	58.4	95.2	94.8	70.3	61.2	321.5	105.0	101.2	69.1	62.0	337.3		658.8
5:15					3269	2405	55.2	58.4												
5:30	140	8.7	9.7	23.9	4095	3281	55.0	58.6	93.2	94.3	71.3	60.7	319.5	104.1	99.2	70.5	63.8	337.6		657.1
5:45					4921	4157	55.0	58.4												
6:00	140	9	9.7	23.9	5748	5035	55.4	58.8	94.6	94.0	72.9	60.8	322.3	105.7	100.7	69.8	63.7	339.9		662.2
6:15					6575	5914	55.2	58.6												
6:30	140	9	9.7	23.9	7404	6792	54.9	58.4	92.0	94.8	71.9	60.7	319.4	103.1	100.0	69.1	61.1	333.3		652.7
6:45					8229	7671	55.1	58.6												
7:00	140	10	9.7	23.9	9055	8551	55.2	58.6	95.6	92.2	70.3	63.3	321.4	102.7	99.2	71.2	62.0	335.1		656.5
7:15					9883	9428	55.2	58.4												
7:30	140	9.5	9.7	24.4	0712	0305	55.2	58.6	95.9	93.3	70.4	63.6	323.2	103.6	100.4	70.5	62.5	337.0		660.2
													321.5					336.2		657.7

IES CANAL COMPANY

D 4, AUGUST 8, 1906

TOTAL	GRAND TOTAL	TIME OF TRAVERSE	MEAN DEPTH	VELOCITY	DISCHARGE CU. FT. PER SEC.	INSTRUMENT USED	DISPLACEMENT CU. FT. PER SEC.	SLIP, %	HEIGHT THROUGH WHICH WATER WAS LIFTED	USEFUL WATER H P.	% EFFICIENCY PUMP AND ENGINE
		1:30–1:34	4.165	4.15	150.6	C. M.	151.3	+ .4	31.61	541.0	
334.6	648.5										
		1:55–2:00	4.167	4.165	151.3	P. T.	149.2	—1.4	31.65	534.2	
		2:02–2:09	4.167	4.238	153.8	P. T.	153.5	— .2			
336.4	659.3	2:27–2:32	4.170	4.170	151.4	C. M.	153.2	+1.2	31.63	548.1	83.13
		2:43–2:50	4.164	4.259	154.5	P. T.	153.2	— .8			
330.8	659.9	3:02–3:06	4.16	4.18	151.4	C. M.	153.4	+1.3	31.62	549.0	83.25
		3:14–3:21	4.163	4.188	151.8	P. T.	153.4	+1.0			
338.0	657.5	3:31–3:36	4.154	4.252	153.8	C. M.	152.8	— .7	31.61	546.4	83.10
		3:45–3:53	4.170	4.268	155.0	P. T.	153.4	—1.0			
335.2	657.1	4:00–4:05	4.164	4.27	154.9	C. M.	152.7	—1.4	31.62	546.2	83.12
		4:15–4:22	4.165	4.184	151.8	P. T.	152.1	+ .2			
337.5	653.7	4:30–4:35	4.165	4.255	154.4	C. M.	153.0	— .9	31.62	541.3	83.71
		4:44–4:52	4.176	4.193	152.4	P. T.	153.8	+ .9			
337.3	658.8	5:00–5:06	4.165	4.28	155.3	C. M.	153.0	—1.5	31.62	547.3	83.08
		5:15–5:20	4.176	4.182	152.1	P. T.	153.2	+ .7			
337.6	657.1	5:30–5:34	4.176	4.19	152.4	C. M.	153.2	+ .5	31.62	548.0	83.39
		5:48–5:55	4.176	4.221	153.5	P. T.	153.0	— .3			
339.9	662.2	6:00–6:06	4.173				154.0		31.62	550.8	83.17
		6:15–6:22	4.174	4.216	153.3	P. T.	153.5	+ .1			
333.3	652.7	6:30–6:36	4.165				152.8		31.62	546.5	83.72
		6:45–6:53	4.167	4.143	150.4	P. T.	153.3	+1.9			
335.1	656.5	7:00–7:07	4.167	4.208	152.7	C. M.	153.5	+ .5	31.62	549.0	83.61
		7:15–7:22	4.167	4.233	153.6	P. T.	153.5	— .1			
337.0	660.2										
					152.86		152.7		31.62	547.86	83.28
336.2	657.7										

TEST OF MAIN PUMPING PLANT, NECHES CANAL COMPANY

Boiler Test, August 8, 1906 — Test of Entire Plant, August 9, 1906

TIME	TEMPERATURES: FEED	CALORIMETER	WATER PUMPED	FUEL OIL	AIR	DRAFT GAGE	QUALITY OF STEAM	FEED WATER POUNDS	TIME	FUEL OIL POUNDS	SP. GR. OIL	BOILER PRESSURE	FLUME NUMBER	TIME OF TRAVERSE	MEAN DEPTH	VELOCITY	DISCHARGE CU. FT. PER. SEC.	INSTRUMENT USED	HEIGHT THROUGH WHICH WATER WAS LIFTED: NO. 1	NO. 2	NO. 3	NO. 4	MEAN	USEFUL WATER H. P.	FUEL OIL: TIME	POUNDS	SP. GRAVITY	TEMPERATURE
1:30	198	290	81.5	93	93	.43	99.1		1:30		9	140	2	8:00– 8:08	4.34	3.694	139.5	P. T.	31.99	31.99	31.88	31.93	31.95		7:25			
									1:45	336			1	8:15– 8:23	4.18	4.168	151.5	P. T.							7:39	672	.9	88
2:00	199	290	81.5	93	94	.43	99.1	7241	2:00	672	9	140	2	8:30– 8:42	4.40	3.618	138.5	C. M.							8:01	1344		
									2:16	1008			1	8:45– 8:52	4.14	4.236	152.5	C. M.	32.09	32.09	32.06	32 0	32.06		8:20	2016	.9	90
2:30	199	290	81.5	94	94	.45	99.1	14482	2:34	1344	.9	140	2	9:00– 9:09	4.40	3.684	141.0	P. T.							8:41	2688		
													1	9:15– 9:28	4.09	4.214	150.0	P. T.							9:02	3360	.9	91
3:00	199	290	81.5	94	93	.46	99.1	21723	2:54	1680	.9	140	2	9:35– 9:43	4.38	3.585	136.5	C. M.							9:23	4032		
									3:13	2026			1	9:46– 9:54	4.08	4.180	148.4	C, M.	32.09	32.09	31.98	32.03	32.05		9:44	4694	.9	92.5
3:30	199	290	81.5	94	93	.48	99.1	28964	3:30	2352	.9	140	2	10:00–10:08	4.38	3.524	134.2	P. T.							10:04	5376		
									3:47	2688			1	10:15–10:25	4.07	4.237	150.2	P. T.							10:23	6048	.9	
4:00	199	290	81.5	93	92	.50	99.1	36205	4:06	3024	.9	140	2	10:30–10:39	4.36	3.686	139.8	C. M.										
									4:22	3360			1	10:45–10:53	4.06	4.463	157.5	C. M.	32.04	32.04	31.93	31.76	31.99		10:44	6720	.898	92.5
4:30	199	290	81.5	92	88	.50	99.1	43446			.9	140	2	11:00–11:08	4.34	3.749	141.4	P. T.							11:05	7392		
									4:40	3696			1	11:15–11:23	4.05	4.403	155.3	P. T.							11:25	8064	.898	95.5
5:00	199	290	81.5	90	87	.50	99.1	50687	4:58	4032	.9	140	2	11:30–11:37	4.33	3.790	142.8	C. M.							11:47	8736		
									5:16	4368			1	11:45–11:53	4.03	4.268	150.1	C. M.	32.04	32.04	31.93	31.96	31.99		11:58	9072		
5:30	199	290	81.5	89	86	.50	99.1	57928	5:34	4704	9											Mean	32.01	1054				
									5:52	5040																		
6:00	199	290	81.5	88	85	.49	99.1	65169	6:11	5376	9																	
									6:29	5712																		
6:30	199	290	81.5	86	84	.48	99.1	72410	6:47	6048	9																	
7:00	199	290	81.5	85	81	.48	99.1	79651	7:055	6384	9																	

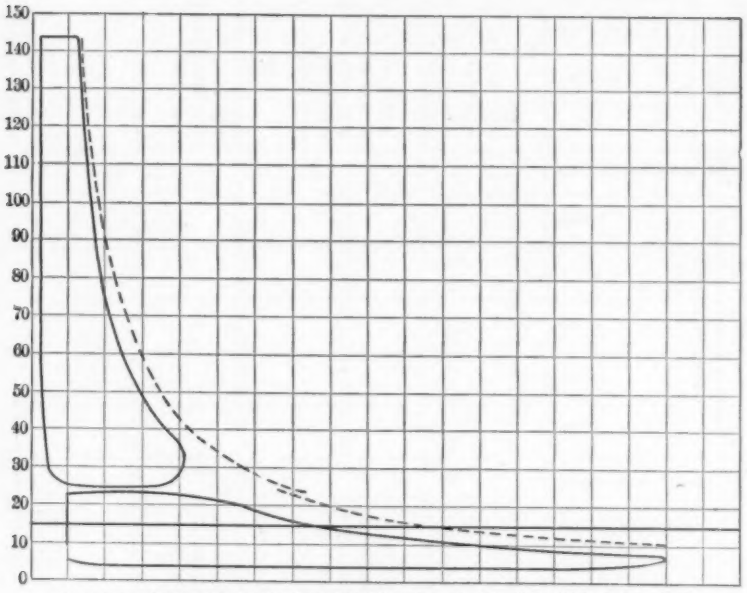

FIG. 10 COMBINED CARDS ENGINE No. 3 HEAD END TIME, 5:30

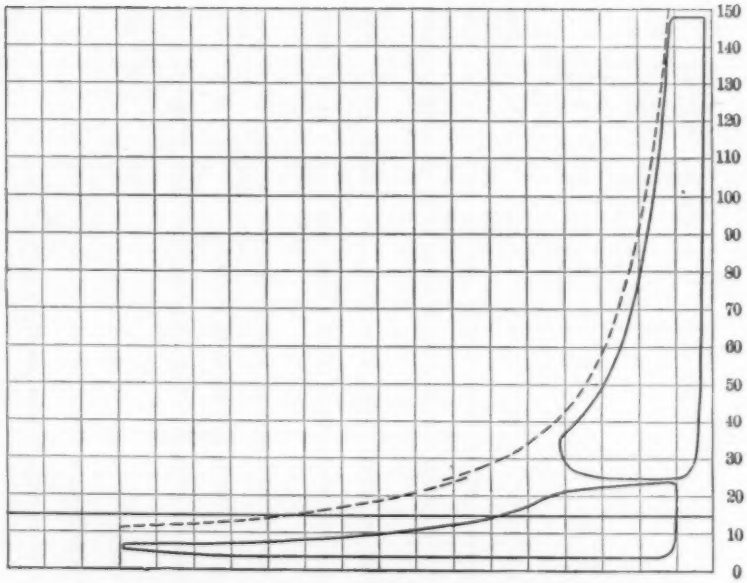

FIG 11 COMBINED CARDS ENGINE NO. 3 CRANK END TIME, 5:30

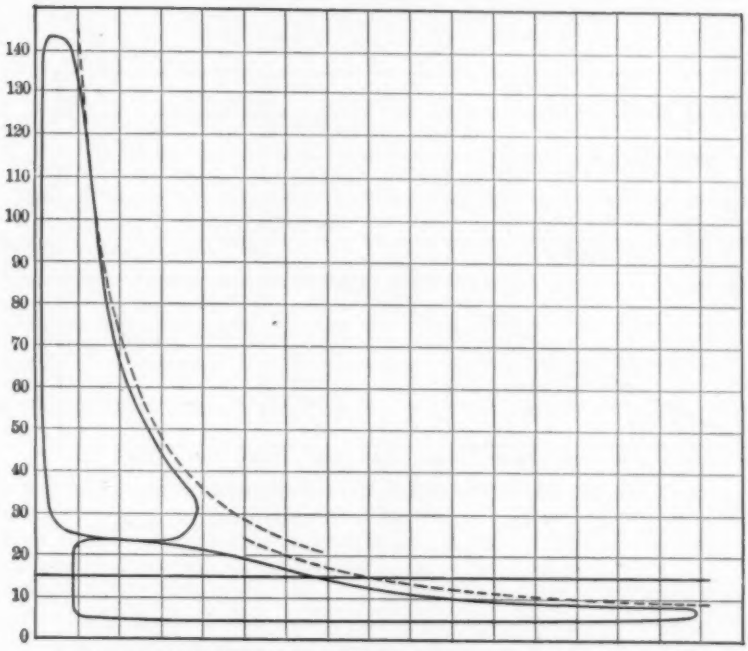

FIG. 12 COMBINED CARDS ENGINE No. 4 HEAD END TIME, 5:30

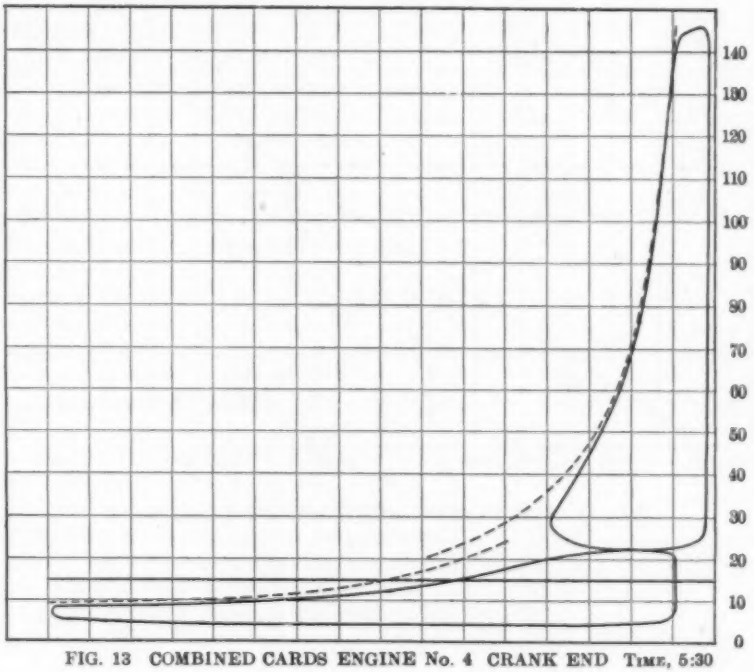

FIG. 13 COMBINED CARDS ENGINE No. 4 CRANK END TIME, 5:30

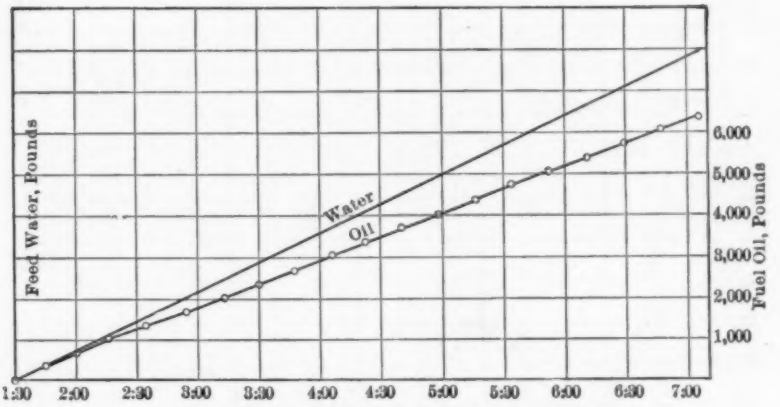

FIG. 14 MAIN PUMPING PLANT, NECHES CANAL CO.
AUGUST 8, 1906

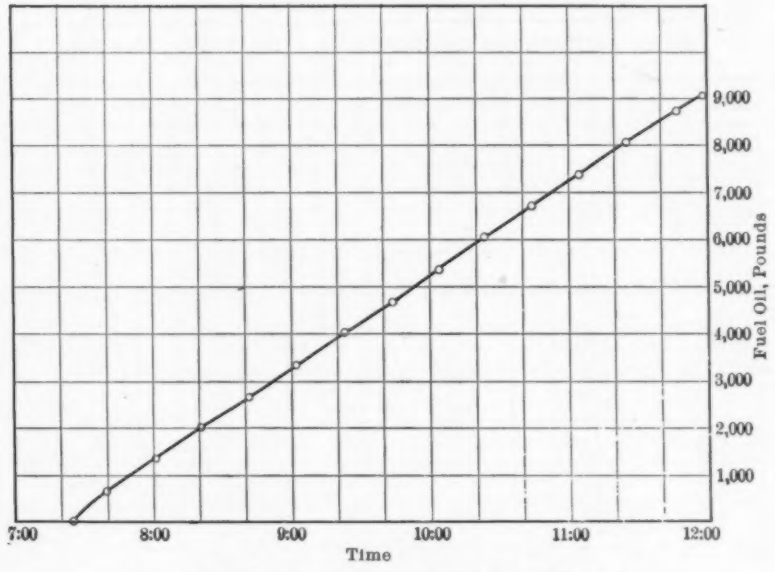

FIG. 15 MAIN PUMPING PLANT, NECHES CANAL CO.
AUGUST 9, 1906

TEST OF MAIN PUMPING PLANT, NECHES CANAL COMPANY, NEAR BEAUMONT, TEXAS

Summary of results

	August 8	August 9
Duration of test, hours	5.592	4.55
Type of engine, tandem compound condensing Corliss, dimensions, 18 x 36 x 48, number operated	2	4
Type of pumps, Connersville cycloidal rotary (operated)	2	4
Mean i h. p., No. 3	321.5	
Mean i h. p., No. 4	336.2	
	657.7	
Difference of level between suction and discharge	31.62	32.01
Cubic feet of water pumped per second (measured)	152.9	291.2
Displacement of pumps, cubic feet per second	152.7	
Temperature of water pumped, degrees F.	81.5	81.5
Weight of water per cubic foot	62.21	62.21
Useful water h. p.	547.9	1054.
Mechanical efficiency of pumps and engines, per cent	83.3	
Heater, Cochrane open	1 No. 7	2 No. 7
Boilers, water tube, Erie City Iron Works	1-400 h. p.	2-400 h. p.
Steam pressure gage	140	140
Temperature of feed, degrees F.	199	
Boiler h. p., basis 34.5 pounds of water from and at 212	442.	
Heating surface of boilers, square feet	3675.	7350.
Heating surface per boiler h. p., square feet	8.32	
Barometer reading, inches of mercury	29.96	
Quality of steam, per cent	99.1	
Ratio, pounds of water evaporated to pounds of fuel oil, actual	12.68	
Ratio water evaporated to fuel oil, from and at 212	13.36	
Barrels of fuel oil per hour (315 pounds)	3.625	6.33
Pounds of oil per minute	19.03	33.23
Pounds of fuel oil per i. h. p. hour	1.736	
Pounds of oil per useful water h. p. hour	2.084	1.892
Heat value of fuel oil, B. t. u.'s per pound	18,790.	18,790.
Heat equivalent of fuel oil per minute	357,550.	624,500.
Pounds of steam per minute	241.4	
Pounds of steam per i. h. p. hour, used by engines, oil burners, vacuum feed pumps	22.02	
Heat required to produce total steam per minute	245,530.	
Ratio of heat in steam to that in fuel oil (boiler eff.)	68.6	
Heat equivalent of i. h. p. per minute, B. t. u.'s	27,900.	

	August 8	August 9
Ratio of heat equivalent of i. h. p. to heat in total steam	.1136	
Ratio of heat equivalent of i. h. p. to heat equivalent of fuel oil	.078	
Heat equivalent of water, h. p. per minute, B. t. u.'s	23,242.	44,710.
Ratio heat equivalent of w. h. p. to heat of total steam	.0947	
Ratio heat equivalent of w. h. p. to heat equivalent of i. h. p.	.833	
Ratio heat equivalent of w. h. p. to heat in fuel oil	.065	.0716
Duty, per million heat units in fuel, millions of foot lbs.	50.56	55.7
Duty per 1,000 pounds of dry steam, millions of foot lbs	75.4	
Cost per barrel, fuel oil, cents	65.	65.
Cost of fuel oil per hour	$2.36	$4.12
Amount of water pumped, gallons per minute	68,530.	130,700.
Cost of fuel to raise 1,000,000 gallons one foot, cents	1.81	1.64
Cost of fuel to raise one acre-foot one foot, cents	.556	.504
Cost of fuel to raise water 20 feet to irrigate one acre two feet deep, cents	22.24	20.16
Cost of fuel to raise water 20 feet to irrigate one acre two feet deep, fuel oil at 50 cents per barrel of 42 gals., cents	17.11	15.51

DISCUSSION

VENTILATION OF THE BOSTON SUBWAY

By Mr. H. A. Carson, Published in October Proceedings

The Author Paragraph 2, p. 50, should read "The aggregate length of the Boston Subway system is 4¼ miles."

Mr. L. H. Woodbridge In answer to anticipated inquiry with reference to certain methods and means employed for the ventilation of the Boston subways and tunnel, and which are not fully set forth in the interesting paper presented by Mr. Carson, a few additional statements are ventured which may be of sufficient general interest to warrant attention.

2 Several methods for ventilating the original subway were considered, one being that proposed by an alien engineer who advocated it as a sure, if not the only "positive" method. The method proposed was the reverse of that employed for ventilating the Liverpool-Birkenhead tunnel, namely: a properly proportioned airway built parallel with, and in close proximity to, the subway, with suitably spaced and dimensioned openings between that airway and the subway; the air to be supplied to the airway by a blower placed midway between stations, and the airway extending from that midway point in each direction toward and nearly to those stations. It was proposed by that method to secure a controllable distribution of fresh air along the entire length of the subway.

3 The method was not approved for reasons of cost, both of construction and of operation, and also because of inefficiency in the supply and the unsuitableness of the use of air in ventilating work. The cost of constructing an airway, say four feet in diameter and nearly the entire length of the tunnel, and of connecting that airway at frequent intervals with the subway, would have been large. The power expended in moving, let us assume, 450 cubic feet of air per second through each of the two branches of such an airway, each branch being some 600 feet in length, would be excessive as compared with that required to move the same quantity of air through the same

length of the subway having a cross-section of 450 square feet. In the case of the airway, the pressure required would be approximately 4.28 pounds per square foot, which multiplied by the area of the 4 feet diameter airway (12.56 square feet), and that again into the per minute lineal flow (2160 feet), would give a total of 116,021 foot pounds per minute for each half of the airway between stations. The same air quantity per minute moved through the subway itself would require the very low pressure of 0.0008 pound per square foot, which, multiplied by the area of the cross-section of the subway (450 square feet), and that product by the per minute lineal velocity of flow (60 feet), gives approximately 20 foot pounds per minute as the frictional work; or approximately one five-thousandth of that work found for the special airway method of ventilating a subway. As one of the principal costs of such ventilation is that of the power required to operate ventilating mechanism, that enormous disparity in work to be done by such mechanism in the two cases made it quite impossible to favor the special airway scheme from the standpoint of operating economy.

4 As to the efficiency of the airway method of supplying air to the subway, it will be observed that the entrance of equal volumes of air at intervals of, let us suppose, 100 feet, would normally result in a cumulative movement of air from a point midway between the stations toward and to those stations. Each of the six 100 feet sections of the subway would then receive a supply of 4500 cubic feet of air per minute. If the impurities which vitiate the air of the subway are assumed to be equally generated along its length, the impurity held by the air of the successive sections from the center to the stations would be uniform, and the air encountered by those entering the stations from the outside would be that carrying the impurity out from the subway through the stations and approaches for outboard discharge. The result would then plainly be a uniformity of atmospheric vitiating contents throughout the subway and stations, and approaches to stations.

5 Some of such contents would be taken up by the air within a few feet of the point of discharge, and some of it 600 feet distant from that point and requiring ten minutes of travel to reach the station, having passed through the six intervening sections between the center and the station point, a condition to be presently noticed as one to be avoided. The longer the distance traveled, the longer the time of retention of the organic matter in the air, and the greater the change toward fermentation and decomposition, and the more offensive the attending odor. A movement of air from center toward stations

would therefore bring to the stations and approaches the worst of the subway air.

6 In the matter of protection against dangerous situations, as those incident to fire or panic, the method of ventilation by auxiliary airway supply is as faulty as it has been shown to be in its mechanical features. In the case of the firing of a car within a subway and between stations, the natural rush of escaping passengers would be toward the stations. If the air traveled in the same direction with those in flight, escape from smoke and heat would be less immediate and complete than if the air moved in a counter direction.

7 So also for the prevention of panic at crowded stations, due to a filling of those stations with smoke and heat consequent upon the accident of fire within a subway, an indraft of fresh and cool air from without is to be preferred to an outdraft at those congested points of smoky and heated air from within.

8 A further reason which favors the entering of air at the stations and the removing of air at points midway between stations, is that the air of the subway most breathed is that at the stations by the waiting crowds. Once in the car, if it be of the closed type, the air breathed is that of the car rather than of the subway proper. Futhermore, the change of air within closed cars is chiefly at stations, when doors are open and the passengers are in exit and entrance. The quality of air at the stations is therefore of more vital importance than is that of the subway except when open cars are in use.

9 The maintenance at the stations of the purest air practicable is additionally advisable because of the impression made on most users of the subway by the quick transition made from the outer to the inner air on entering the stations and when the olfactory senses are keen, and any taint in the air entered is quickly detected. If on entrance the air is noticed as repulsive, a mental impression is made which is likely to be persistent, and to magnify and aggravate such defects as actually exist, and to find expression in private and public criticism and condemnation of atmospheric conditions in the subway. If there must be offensiveness to keen olfactories in air escaping from the subway, it had far better be where the boy in the picture stands (Fig. 5, p. 56, October Proceedings) than where patrons enter the subway.

10 Therefore, for the maintenance of the better hygienic conditions in the subway; for the more effective use of air; for the protection of patrons in case of fire; for the prevention of panic at stations; and for the subordinate effect of insuring favorable first impressions on the users of the subway, the intake of air has, in the Boston

instance, been made at the stations and the outlet at points midway between them.

11 In general, the minimum quantity of air which the mechanical system for the ventilation of the subway is planned to move is, as has been stated by Mr. Carson, equal to a flow of one linear foot per second from each station toward each center of discharge. The maximum speed of the fans was planned to be such as to discharge 50 per cent in excess of the minimum quantity named. If the cross-section of the subway is 450 square feet, the minimum per minute air flow through the discharge fan, or fans, between stations should be 54,000 cubic feet, enough to supply 1000 breathers with such reasonably pure air as to give a carbon dioxid increment of less than 2 parts in 10,000 of air. If a rise of five degrees of temperature be allowed, due to the transformation of mechanical into thermal energy, the corresponding rate in horsepower of work so transformed would be 115 between stations. Allowing an average electric input of ten horse power to each car, eleven cars continually running between stations located 1200 feet apart would be provided for.

12 Such, briefly stated, are the reasons for the adoption of the method of using air employed in the ventilation of the Boston subway and tunnel.

13 A few words may be allowed with reference to the type of fan selected for the ventilating work. The two requirements governing the selection of fans for this purpose were, first, a minimum power expenditure, and, second, a minimum noise of action.

14 The choice lay between the standard cased blower type, the uncased radial, and the axial fan. Reference to a few of many tables compiled from the results of an extended series of tests made at the Massachusetts Institute of Technology on the performance of a variety of fans, will aid to an understanding of the reasoning which led to the choice of the type used. The blower type of unclosed fan, and the open and radial types, which were subjected to test, were 36 inches in diameter. The axial fan was of the Blakeman type, and 30 inches in diameter, and the tables show results for these fans when run at a speed of 500 revolutions per minute. The areas of inlet to all the fans were practically the same, a part of the experiments having had reference to a determination of the powers required to move air through a given aperture and against various pressure differences by the several types of fans used. While the tables do not apply directly to fans of other sizes, they indicate the law which governs the performance of their respective types and furnish a basis for

computation with reference to such performance in fans of any size and run at any speed.

500 R. P. M.

TYPE OF FAN	PRESSURE INCHES OF WATER	VOLUME OF AIR. CU. FT. PER M	HORSE POWER INPUT TO FAN	FT. LBS. PER CU. FT. OF AIR MOVED
Sturtevant Cased Fan	1.60	0	1.09	
Double Inlet	1.685	1000	1.225	40.42
	1.60	2350	1.56	21.90
	1.50	3160	1.75	18.27
	1.25	4600	2.06	14.77
	1.00	5870	2.30	12.95
	0.75	7230	2.65	12.09
	0.65	8400	2.95	11.59
Sturtevant Cone	1.095	0	1.13	
Uncased Fan	1.00	1750	1.28	24.13
Single Inlet	0.90	2800	1.30	15.29
	0.80	3800	1.34	11.63
	0.70	4650	1.43	10.15
	0.60	5375	1.56	9.57
	0.50	6025	1.73	9.47
	0.40	6525	1.88	9.51
Briggs-Meigs	0.893	0	0.42	
(Woodbridge)	0.8	1325	0.575	14.32
	0.7	2425	0.70	9.53
	0.6	3350	0.81	7.95
	0.5	4125	0.865	6.92
	0.4	4760	0.89	6.17
	0.3	5250	0.92	5.78
	0.26	5400	0.93	5.69
Blackman Axial Fan	0.55	0	0.76	
"Forward"	0.50	450	0.698	51.18
	0.40	1400	0.58	13.64
	0.30	2275	0.475	6.88
	0.20	2925	0.383	4.32
	0.10	3425	0.30	2.89
Blackman Axial Fan	0.53	0	0.47	
"Reversed."	0.50	550	0.46	27.60
	0.40	1725	0.40	7.65
	0.30	2750	0.34	4.08
	0.20	3475	0.31	2.94
	0.14	3850	0.30	2.65

15 A cursory examination of the table makes evident the well established fact that the cased radial fan is a superior type for use

when air is to be moved against any considerable pressure. No other would have been considered had the auxiliary airway method of ventilation been adopted.

16 The ordinary unhoused radial fans are typified in the Sturtevant "cone" pattern. When that fan is made double inlet, to bring it into correspondence with the double inlet blower fans of the cased type, it will move against a resistant pressure indicated by one inch water column approximately 60 per cent of the air moved by the cased blower of equal diameter, and when run at the same rotary speed. As resisting pressures decrease, however the air moving capacity of this type of unhoused fan is shown to increase, and eventually to exceed that of the housed fan. Furthermore, the per cubic foot work by the uncased fan is nearly double that of the cased fan at the resisting pressure of 1 inch water column, and at the lower resisting pressures tabulated equality is reached, and with indications favorable to the uncased fan.

17 The cased fan is not adapted to low pressure work, for the reason that the pressure existing within the casing itself (and which is potent among the conditions producing flow through the fan orifice), is one against which the impelling fan must work.

18 The form of the Briggs-Meigs type of fan reduces stray, or waste, work, first, by a contraction of the perimeter area to about one-fourth that of the standard cone fan, so preventing regurgitation; and, second, by a form of blade designed to avoid imparting to the air moving out radially through the fan any unnecessary tangential motion. The narrowness of the peripheral opening reduces the volume of flow under any given condition of rotary speed and resisting pressure, but both factors of contracted perimeter airway and curved blades reduce the per cubic foot work to approximately 60 per cent of that expended by the Sturtevant type of cone fan. For higher pressure, the efficiency of the Brigg-Meigs type of fan falls off, as compared with that of the Sturtevant fan, because the curved blades of the former are not as well adapted as are the radial form of the latter to move air against opposing pressure. At a point between pressures of 7/10 and 8/10 inch of water column, the two types are of equal efficiency as measured by the per cubic foot work done in each case.

19 The Blackman fan is the only one of axial type of the performance of which a tabular exhibit is here made, for the reason that this fan when run in a reverse position, that is, when mounted on the delivery side, rather than, as in the regular manner, on the feed side of the aperture, gives both capacity and efficiency results superior to those obtained by any of the several other fans of the axial type tested.

20 It is of importance to note, that the characteristic curve of the radial fan, whether cased or open, would show a minimum energy input to fan when no air is being moved through it and the system with which it is in connection, and an increasing energy input as the volume of air passed through the fan and system is increased; and, second, that with the axial fan the reverse is found to be true, since for any given speed the less the effective work done by the fan the greater the energy input to the fan; and the larger the effective work the less the energy input, all of which appears less strikingly from an inspection of the numerical tables than it would from an examination of graphical tables, could they be presented with this discussion.

21 Because of the very small resisting pressure against which fans would operate to produce a slow flow of air through the subway as a conduit, and through vent ways from the fans, carefully designed for the purpose of reducing frictional and other resistance to a minimum, the choice of fans was narrowed down to the Briggs-Meigs radial, and the Blackman axial reversed. The subway construction, as well as the admissible dimensions of ventilating chambers, imposed a limit on the size of permissible fans.

22 A radial fan with generous inlet requires about the same wall aperture as that which an axial fan would fill. Thus a 30-inch axial fan fills about the same wall aperture as is required by a 36-inch Briggs-Meigs radial fan.

23 By reference to curves, from which the tables are made up, it appears that under a resistance pressure of 2/10 inch water column, the radial fan moves 5675 cubic feet per minute, as against 3475 cubic feet by the axial reversed. Therefore, at that pressure, the speed of the axial fan would have to become 64 per cent greater, or 820 r.p.m. to make its output equal to that of the radial; and as energy input to fans of given size varies as the cube of speeds, the power would be increased practically fivefold, and would become $0.34 \times 5 = 1.55$ h.p. for moving 5675 cubic feet of air per minute, which would make the cubic foot work nine foot pounds as against five for the radial fan. Furthermore, the noise resulting from such high speed of the axial fan would prove a serious objection to its use. The action of the radial fan of the Briggs-Meigs type requiring the same wall aperture and moving the same air quantity would be unobjectionable.

24 The subject tempts to further elaboration and discussion, particularly in connection with the ventilation of the tunnel, and with computations made (and to some extent unmade) for determining resisting pressures, fan sizes, forms and speeds, and required operating powers; but this contribution to a discussion of the lead-

ing paper must close with a protest against the indifferent use to which carefully devised and provided means are at times and in places found to be put, and also against the fouling of subway walls and floors by, perhaps diseased, and certainly unwholesome expectorators. Inevitably, a subway grows dirtier with age, and in corresponding need of increasingly energetic ventilation if the air within it is to be kept free from offensive and morbific taint. Let subways and tunnels be liberally furnished with illuminated prohibitions against polluting offenses, and let offenders be hygienically dealt with by heroic processes. No practicable artificial ventilation can sweeten a dirty subway.

SAW-TOOTH SKYLIGHT IN FACTORY ROOF CONSTRUCTION

By Mr. Fred S. Hinds, Published in October Proceedings

The Author The cut (Fig. 6a), while not in the line of a machine shop, very finely illustrates the two-story type suitable for cotton factories with the application of saw-tooth skylight. This design is used where land is too valuable for manufacturers to consider a one-story factory. It also follows along the line of shop economics in the arrangement of benches and tools in this second story.

Error Reference to figures, in paragraph 39, should read "illustrated by Fig. 11" instead of "illustrated by Fig. 9 and Fig. 10."

Mr. G. R. Henderson The author of this paper refers to the proper angle for placing the skylights in the saw-tooth, and while, no doubt, this angle is correct from a theoretical point of view, as far as proper diffusion of the light is concerned, yet from practical considerations, in connection with the structure of a building, it is sometimes desirable to place these windows vertically. This will be illustrated by the accompanying cuts, which represent a locomotive, erecting and machine shop now being constructed by the Missouri, Kansas, and Texas Railway from plans prepared by the writer. Fig. 1 shows the west elevation and Fig. 2 the east elevation. The saw-tooth construction will be noticed on each side of the central or higher section, and it will be seen that the windows in this saw-tooth are placed in a vertical plane. Fig. 3 makes the arrangement somewhat clearer, and while the saw-tooth windows are not actually shown,

FIG. 6a WIDE TWO-STORY SHOP JOHN THOMPSON PRESS COMPANY'S PLANT

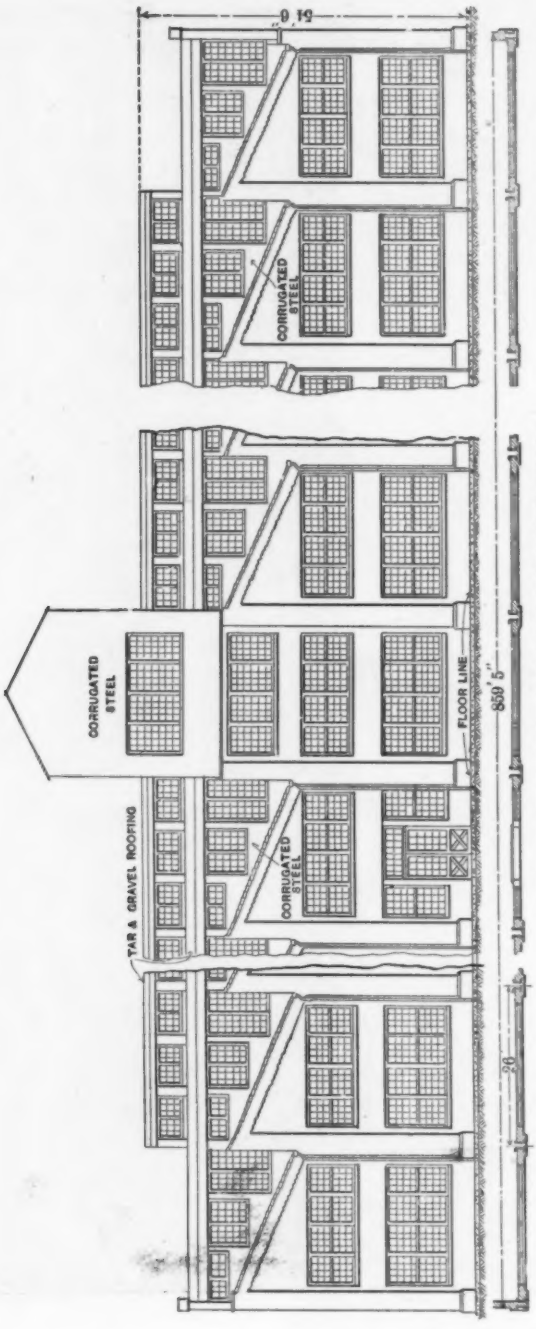

FIG. 1 WEST ELEVATION LOCOMOTIVE SHOPS

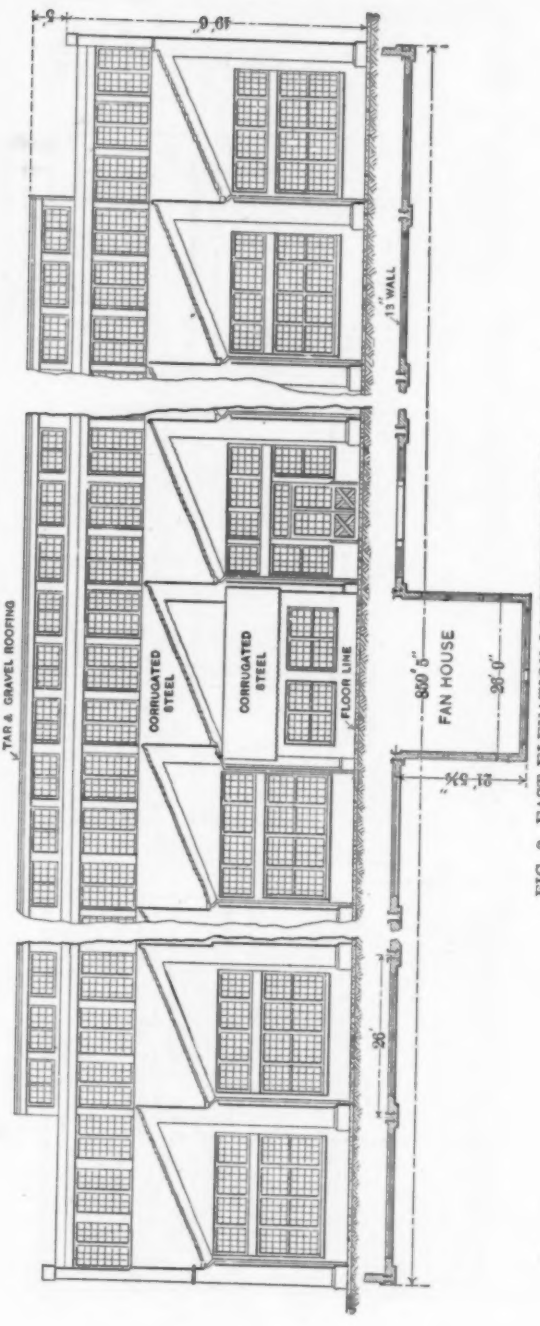

FIG. 2 EAST ELEVATION LOCOMOTIVE SHOPS

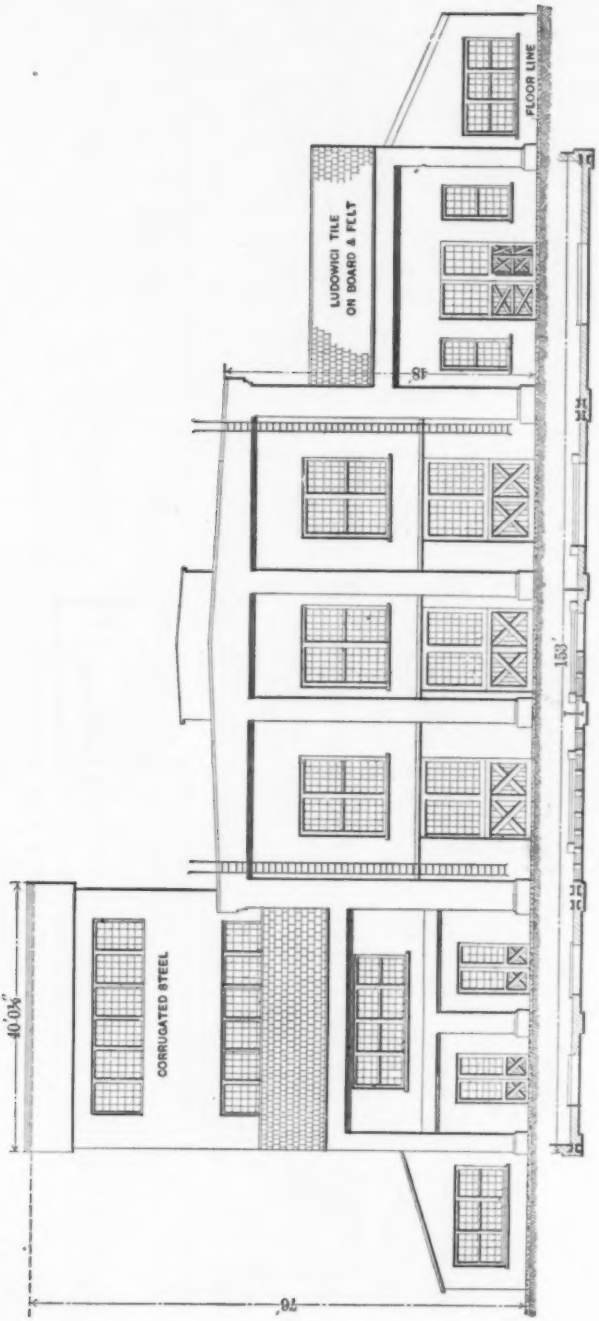

FIG. 3 END ELEVATION LOCOMOTIVE SHOP

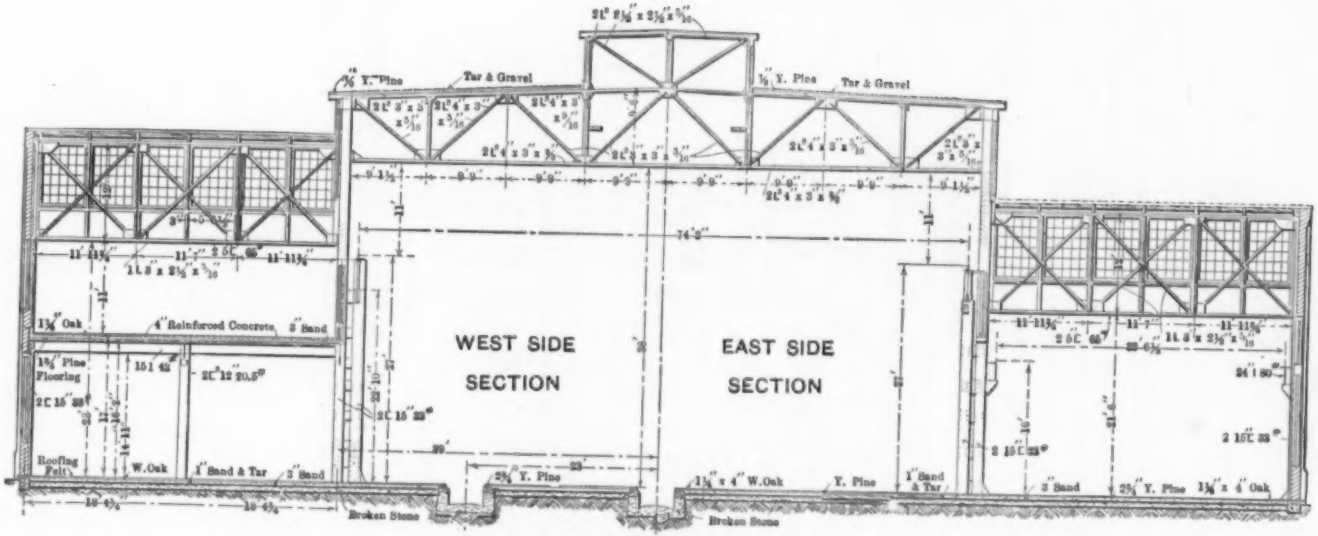

FIG. 4 SECTION OF LOCOMOTIVE SHOP

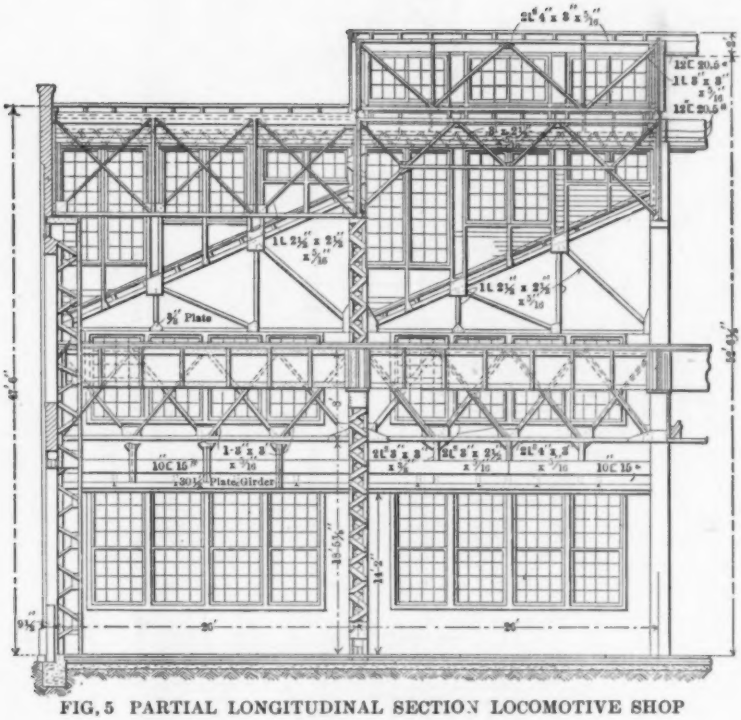

FIG. 5 PARTIAL LONGITUDINAL SECTION LOCOMOTIVE SHOP

they are located at the opposite side of the portion where the tiling is indicated.

2 In Fig. 4 a section of the building is shown in which it will be noticed that the saw-tooth windows are placed close to a horizontal truss. In designing this building to stand the heavy winds which exist upon the Western prairies, it was found that by utilizing this truss as a portal bracing, considerably less material was needed in the building than if this truss were omitted or disposed of in some other fashion. The depth of truss being 12 feet, it gives a very great amount of rigidity to the structure and at the same time lends itself very nicely to supporting the triangular trusses which appear in Fig. 5, the hypotenuse of which supports the tile roofing, and the vertical sides constitute the window face of the saw-tooth. Four triangular trusses are carried from these parallel trusses, one at each row of columns and one at each of the two middle apices. As the high end of the triangular truss is attached to one side of these parallel trusses, the top cord is properly stiffened and at the same time the lower cord of the triangular truss is designed so that shafting timbers, etc., could be suspended from it, making not only a rigid roof construction, but a suitable support for shafting.

3 This construction, we think, works out much better in a building of this sort than if the skylight windows were inclined. The windows can also be made in the form of ordinary glazed sash, thereby reducing the cost and decreasing the danger of leakage and enabling us at the same time to construct a building of great stiffness and transverse strength, without interfering with the lighting qualities.